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MAY 77 W PATTERSON F33615-74-C-1173

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AFAL-TR-76-190

F4E FIRE CONTROL SYSTEM SIMULATOR
F4E AUSTERE/HEADS UP DISPLAY (HUD)
SEAFAC PROGRAMS

Westinghouse Defense & Electronics Center
Baltimore, Maryland

AIR FORCE AVIONICS LABORATORY

May 1977

TECHNICAL REPORT AFAL-TR-76

Final Report for Period 1 April 1974 - 1 January 1976

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This final report was submitted by Westinghouse Electric Corporation under Contract F33615-74-C-1173, Project 69DF, Task 01, Work Unit 21 for the U.S. Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio 45433. Skip Wenk was the Westinghouse Program Manager. This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DODD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS). This technical report has been reviewed and is approved for publication.

R E Deal — Robert S. Hill

Asst Chief, Recon & Weapon Delivery Division - RW

Program Manager

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

F-4E Austere HUD and SEAFAC Programs

The two major tasks performed under this contract are:

1. To aid the Air Force in the establishment and support of a Systems Engineering and Avionics Facility (SEAFAC) at Wright-Patterson Air Force Base.

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19. KEY WORDS (Continued)

Radar Automatic Acquisition
Radar Feedhorn Improvements
Altitude Line Interference

20. ABSTRACT (Continued)

The objective of SEAFAC is to provide a capability to solve avionics systems problems utilizing digital computers and systems programming technology. The end product was an Air Force constructed software facility trained personnel and a training software package.

2. To establish and support a flight test program conducted at AFFTC for the purpose of evaluating a Heads Up Display in Air-to-Air gunnery and missile modes and in aided visual air-to-ground conventional weapon delivery.

The program required the modification of Air Force surplus (B-57G) digital computers, modification of an F-4E aircraft, establishment of hardware and software support facilities, operational and support software generation, flight test support, and data reduction.

The program was to be conducted in four phases:

A. HUD Evaluation
B. Weapon Firing
C. Air Combat Evaluator Testing
D. Avionics Improvements

Phase A was completed.

A Westinghouse designed digital automatic acquisition system was evaluated under Phase D. Phases B and C were deferred pending returne of the F-4E to Edwards AFFTC following extensive aircraft modification to bring it to current F-4E configuration.

FOREWORD

The final report consolidates two volumes into one volume as follows: Volume I, Phase A the F-4 Fire Control Systems Simulator, F-4 Austere/ Heads Up Display (HUD), and SEAFAC Programs; Volume II, Phase D the F-4E Austere/HUD Program, Radar Modification.

The Austere HUD/Gunsight Program is a multiphase program dealing with improvements to the Air Force F-4E operational inventory aircraft. Phase A was concerned with improving the pilot's display and improving the gunnery modes, as well as establishing Air Force Systems Engineering Avionics Facilities (SEAFAC), as well as an F-4E Fire Control Simulator hot mockup. Phases B and C deal with air combat evaluation modes and sensor coordination modes planned in the future, and Phase D deals with APQ-120 radar improvements which is the subject of this report.

This report was prepared by Westinghouse Defense and Electronic Systems Center, Baltimore, Maryland 21203. This was done under contract number F33615-74-C-1173, P00001-P00004, Project 69DF, Task 01, Work Unit 21. The report dates are 1 April 1974 through 31 December 1975. The submittal date is January 1976. This report spanned the period of a number of project managers including: Capt. John Koger, Major Vic Trouy and Cap. Bob Hill, Program Manager, F4E Austere HUD, Wright-Patterson AFB, AFAL. The Westinghouse program people included: Skip Wenk, Program Manager; Walter Patterson, Engineering Manager; Jim Rowe, SAEFAC Engineer; Dennis Heinke, Integration Engineer; Bruce Klinger, Systems Engineer; Stan Slocum, Aircraft Modification Engineer.

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SECTION I
INTRODUCTION

This Final Phase A report covers two major task areas of this contract. One is the establishment and support of the Air Force-ASD/ENA Seafac Facilities in Building 485 at Wright-Patterson Air Force Base ~~(Section 1.1 to 1.2.4)~~. The second task is the establishment and support of an F4E (aircraft 304) flight test program at the Air Force Flight Test Center for evaluating an Austere HUD in mission modes of air-to-air missile, air-to-ground weapons, and an air-to-air gunnery mechanizations. This second task required a Class II Modification to an F4E aircraft, including the installation of new ewquipment in aircraft, the establishment of data and analysis facility at Edwards Flight Test Center, the establishment of ground support facilities for the new equipment and mechanizations, the flight test support, the adaptation of the gunnery modes previously flown on an F106 aircraft program, the implementation of representative air-to-air missile and guns and air-to-ground programs to drive the HUD, the necessary modifications to surplus GFE equipment and the installation and operation of Westinghouse support software facilities at Seafac, the Air Force Academy and the Air Force Flight Test Center (AFFTC). In addition to the Westinghouse effort, the Air Force had support from the Air Force Academy and AFFTC in the analysis and evaluation area. A simplified Seafac facility was installed at the Air Force Academy on this contract. Also, the Air Force had support from McDonnell-Douglas Aircraft Company for the analog instrumentation Class II Modification program

on aircraft 304, plus support from TI on the HUD through the Avionics Lab, and from Honeywell on the gunnery mechanizations.

In order to save program costs, the Seafac facilities were utilized in order to perform the initial ground systems integration tasks.

Most hardware was from government surplus or developed on other contracts and used or tested on this contract.

The first task (establishment of Seafac) was successfully completed and used successfully in the second task (F4E Austere HUD). The Air Force had/and still has other internal programs for Seafac usage concurrently with the second task. No serious time conflict in use of Seafac facilities on concurrent programs resulted except in the use of a static simulator. A second unit had to be developed for the F4E Austere HUD Program and shipped to the Air Force Flight Test Center while the first simulator was used at Seafac.

1.1 PROGRAM OBJECTIVE SEAFAC

The Seafac Program was to assist the Air Force in the establishment of an avionics software laboratory at Wright-Patterson Air Force Base. The objective of which was to provide a capability to solve system problems in avionics using comptuer systems programming, including the ability to conduct laboratory software demonstrations. The end product was an Air Force contructed software facility, trained personnel, and a training software package. It was a low-cost, fast response program in which available Air Force equipment was set up for the purpose as

quickly as possible, but in advance, an existing Westinghouse software laboratory was set up at Wright-Patterson Air Force Base, complete with trained personnel and applicable software.

1.2 TASKS PERFORMED

1.2.1 A support software package was installed on the CDC 6600 at Wright-Patterson Air Force Base. It enables the generation of programs for the AN/AYK-8 airborne computer, as well as the Westinghouse Millicomputer family.

1.2.2 An existing software laboratory system from Westinghouse-Baltimore was temporarily transferred, on a loan basis, to Wright-Patterson Air Force Base. Its purpose was to provide equipment for early training of Air Force personnel. This task included normal maintenance of equipment at Wright-Patterson Air Force Base.

1.2.3 A software course and workshop was presented to Air Force personnel at Wright-Patterson Air Force Base. This consisted of: a) series of 10 lectures on the fundamentals of airborne computer systems operational programming, b) utility software programs and listings for use with the Air Force facility, c) programmers manuals and support software instruction manuals, d) instructions on use of the support software package.

1.2.4 Engineering consultation and services were provided on a continuing basis in order to enable the Air Force personnel to perform or obtain the following elements of the Seafac system: a) design interfaces to the AN/APQ-120 radar in the weapons delivery system, b) adapt an AN/AYK-8 computer and associated materials from the SADRAM program to provide

replacement of the Westinghouse software laboratory system, c) design a static aircraft simulator and wiring harness, d) prepare specifications for procurement and integration of a Textronics 611B storage tube display and hard copy unit, provide for integration of a heads up display, hand controller, and ASR-33 teletype, e) provide various cabling and connectors, and f) provide definition of interface for integration of a dynamic simulator using an AN/AYK-8 computer with necessary modifications.

SECTION II

PROGRAM OBJECTIVE F4E AUSTERE HUD PROGRAM

The objective of the program is to develop and demonstrate Austere HUD concepts, to assess risk, and define integration problems for application to F4E aircraft.

2.1 APPROACH

The approach is to modify aircraft 304 at Edwards Air Force Base using Class II Modification, to drive a GFE TI Optical Display Unit (ODU) as shown in figures 1 and 2 by a GFE digital computer, mechanize gunnery solutions, and air-to-air and air-to-ground mechanizations such as to derive the HUD's symbology in representative weapons modes. A GFE digital scan converter is also installed in the aircraft along with the provision for using flight control rate and acceleration data for the gunnery solutions. Westinghouse was to do the complete operational software including incorporating a Honeywell generated gunnery mechanization software. The Air Force would do all the necessary data reduction programs through support from the Air Force Academy and McDonnell-Douglas would do the instrumentation modification for aircraft 304. The Seafac facilities at Dayton at ASD/ENA, Wright-Patterson Air Force Base would be utilized for the ground testing and software generation before installation into the aircraft.

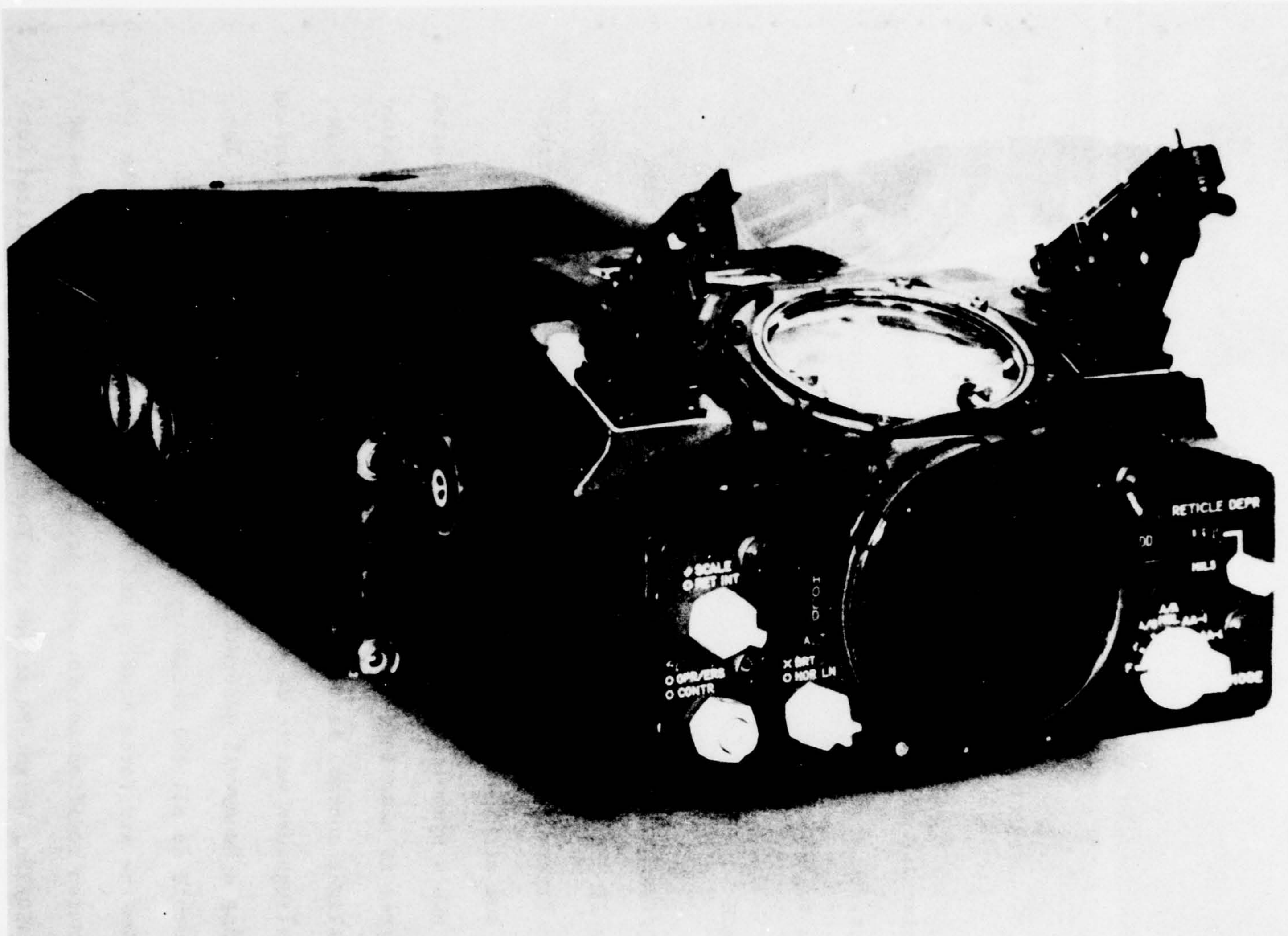

Figure 1. TI AUSTERE/HUD SIDE VIEW

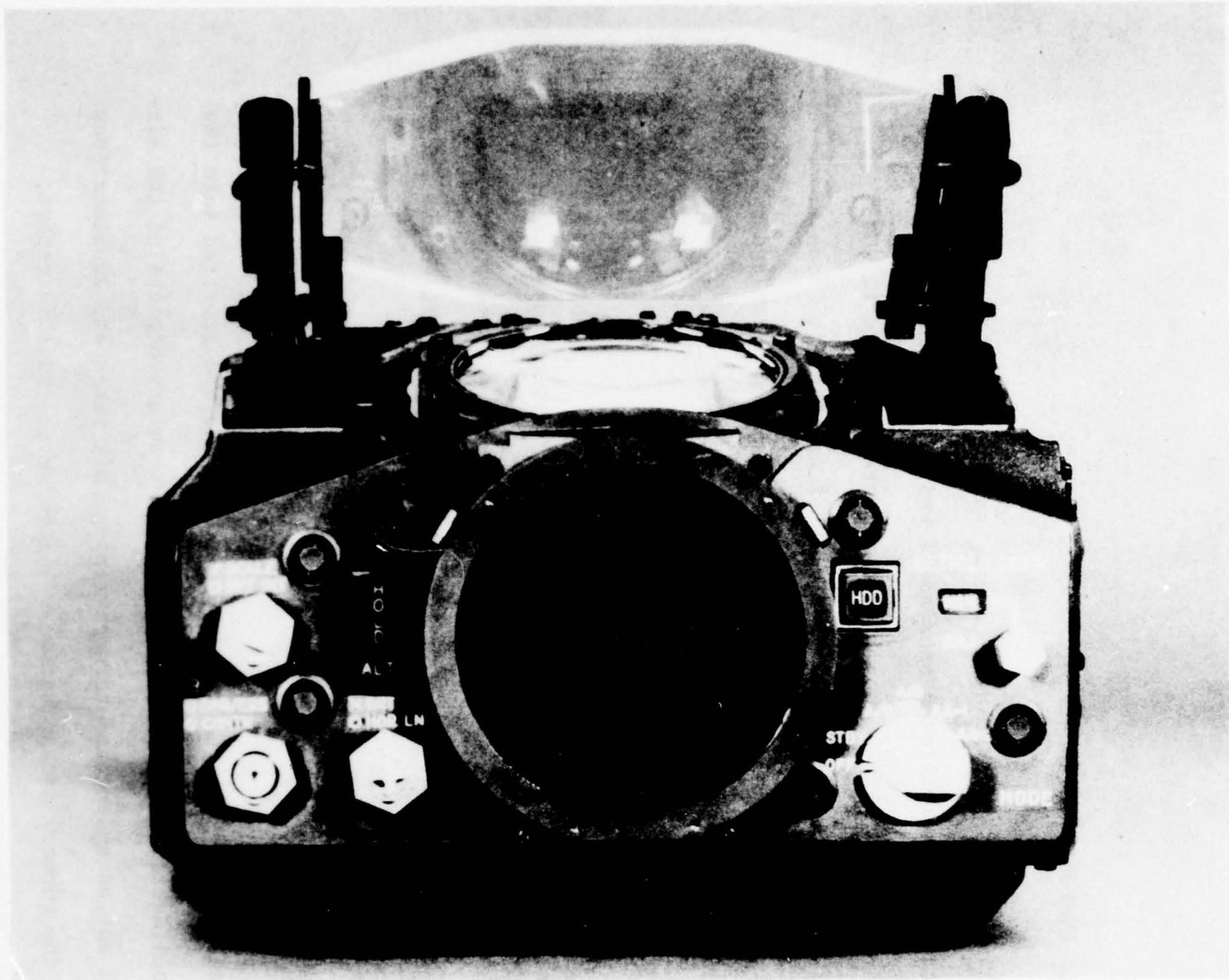

Figure 2. TI AUSTERE/HUD FRONT VIEW

2.2 THE HUD COMPUTER INTERFACE

The drive capability between the computer and the ODU/digital scan converter had to be established between TI and the GFE AN/AYK-8 computer. Appendix A1 is the AN/AYK-8 Output Channel Interface with TI HUD specification generated in conjunction with TI and the Air Force Project Management; implemented as a change to the AN/AYK-8 computer and verified through ground testing at Seafac as well as in aircraft 304.

2.3 CLASS II MODIFICATION KIT

A Class II Modification kit was prepared by Westinghouse, submitted to Edwards Air Force Base for implementation by Air Force Base personnel. Appendix A2 contains excerpts from the report, the full kit is available at Edwards Air Force Flight Test Center.

2.4 FLIGHT CONTROL SAFETY ANALYSIS

A special report was generated by Westinghouse and inserted into the Class II Modification to assure that the flight safety aspects of the aircraft would not be endangered through tapping off rates and accelerations for use in the gunnery mechanizations. Appendix A3 is this report; which is also one of the required data items of the contract.

2.5 F4E AUSTERE HUD FUNCTIONAL SOFTWARE SYMBOL SPECIFICATIONS

Westinghouse was given artist concepts of the displays the Air Force desired for the following weapons modes:

1. Air-to-air gun ALCOSS using radar range and manual range. Figure 3 is the artist concept of it.

2. Air-to-air gun Tracer for both radar range and manual range. Figure 4 is the artist concept.

3. Air-to-air Missile Mode is shown in figure 5, the artist concept.

4. Air-to-ground Manual Mode is shown in figure 6 which is the artist concept.

5. Air-to-ground Automatic is shown in figure 7, the artist concept.

6. Test Modes are shown in figure 8.

A complete set of HUD specifications had to be generated in order to provide the programmers with the data to generate the HUD displays as well as to generate the scaling factors and parameters needed in the various mechanizations. Appendix A4 is a complete list for the specifications of various modes mechanized. In every instance it appears that we have met the requirements of the mode symbology display requirements of the contract.

2.6 MODES MECHANIZED

Five modes have been mechanized. They are two gunnery modes (digital ALCOSS and Tracer), long range intercept missile mode (AIM-7F), and two bombing modes (manual and automatic CCIP).

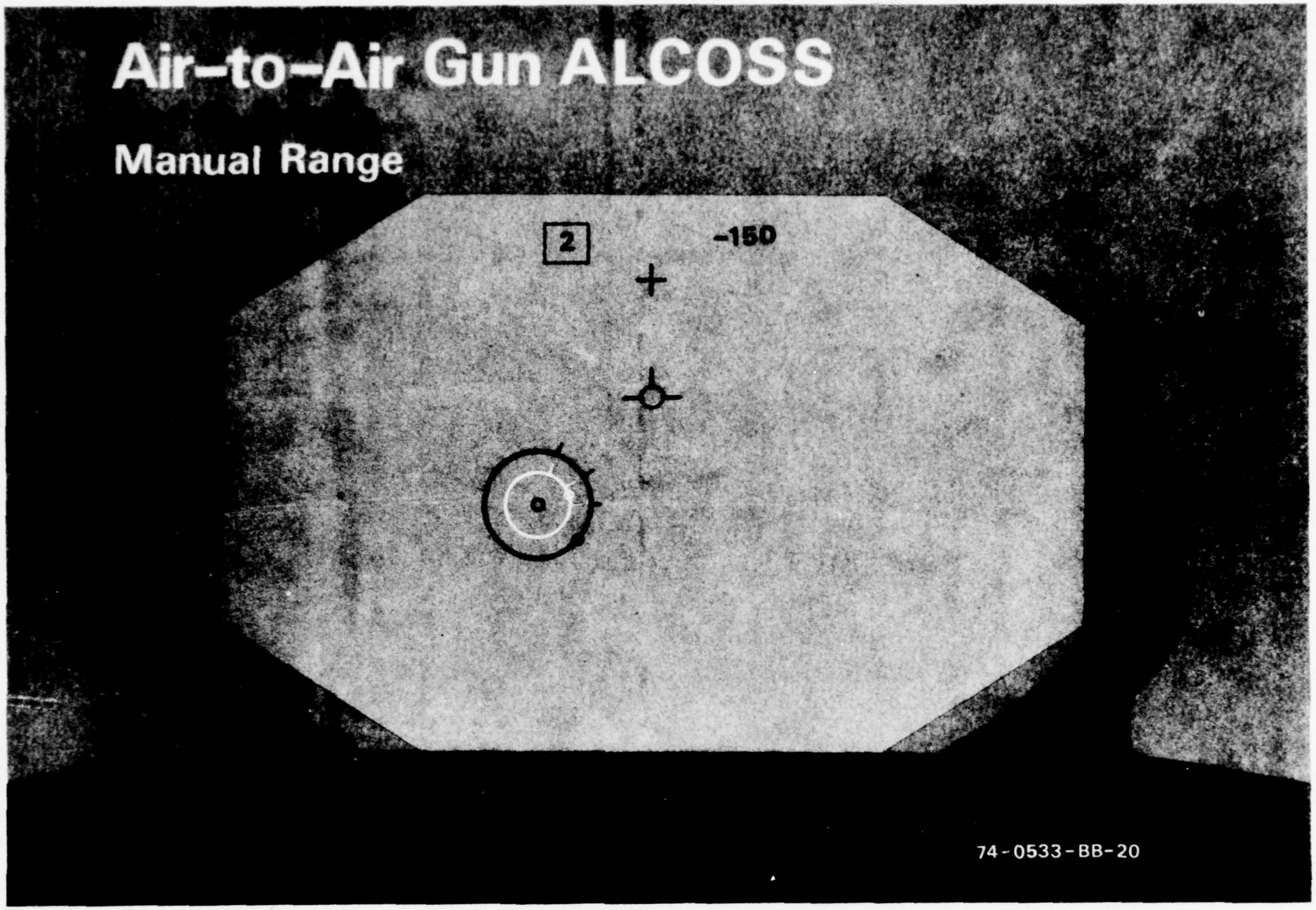

Figure 3. AIR-TO-AIR GUN ALCOSS USING RADAR RANGE AND MANUAL RANGE

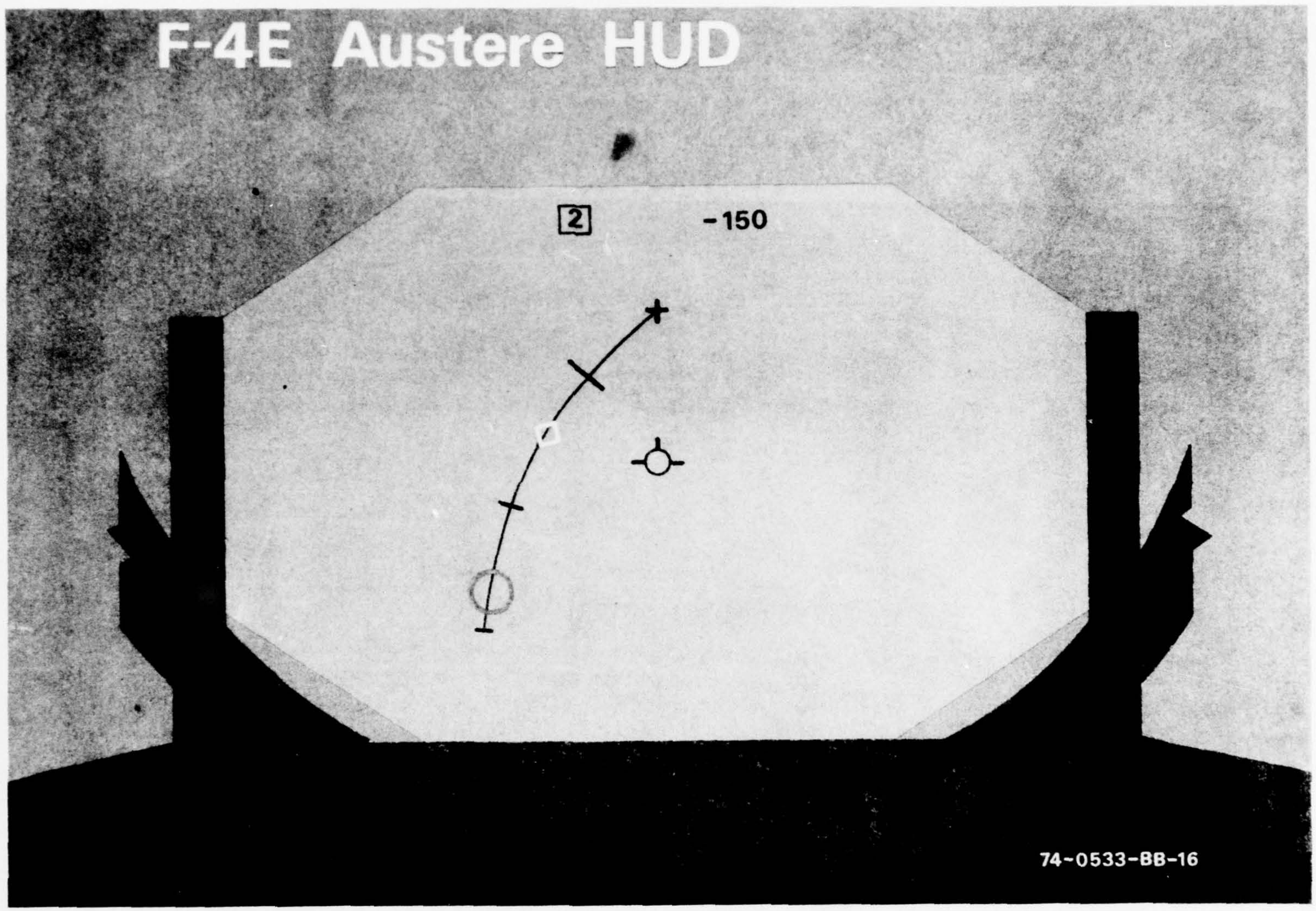

Figure 4. AIR-TO-AIR TRACER FOR BOTH RADAR RANGE AND MANUAL RANGE

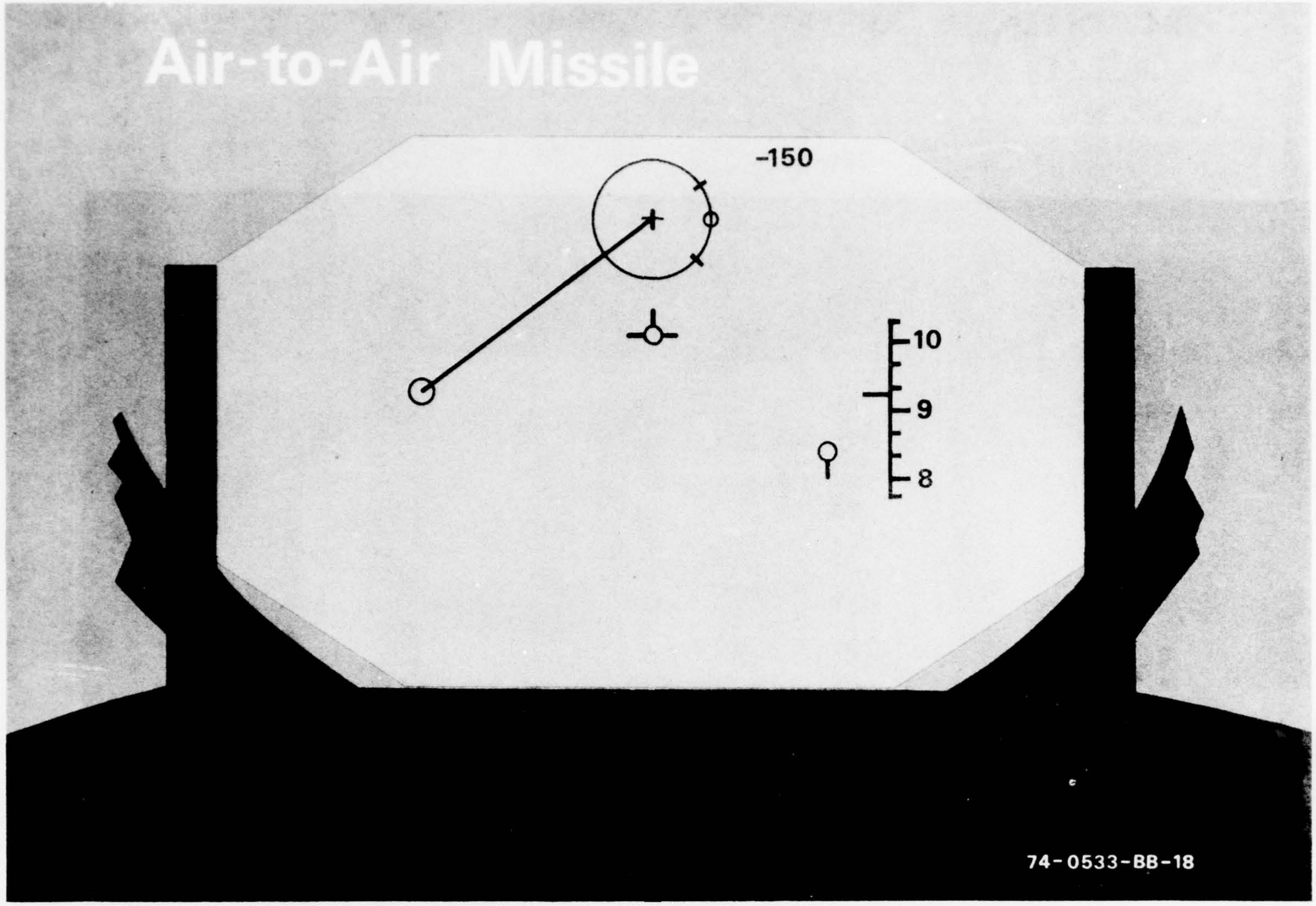

Figure 5. AIR-TO-AIR MISSILE MODE

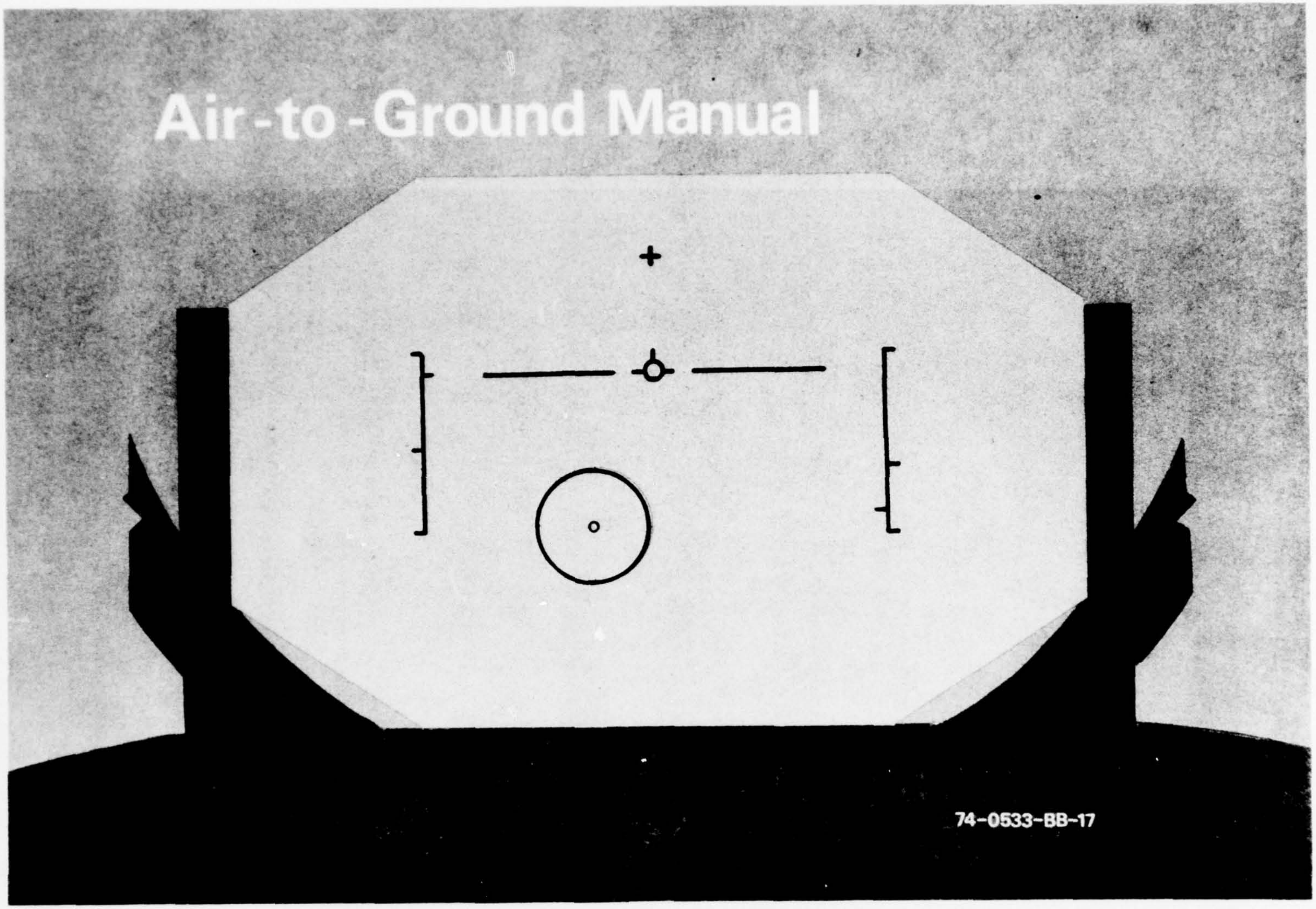

Figure 6. AIR-TO-GROUND MANUAL MODE

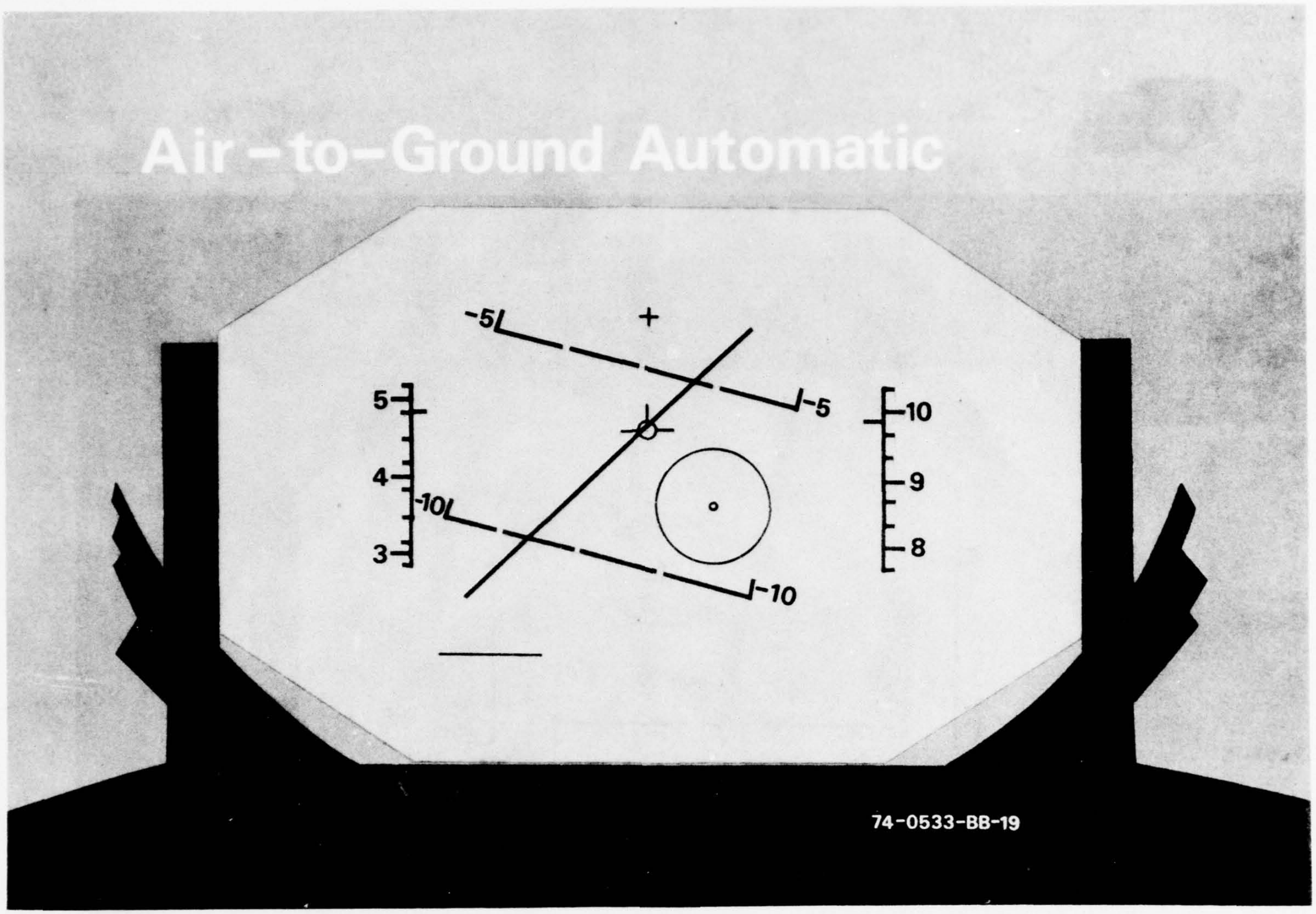

Figure 7. AIR-TO-GROUND AUTOMATIC

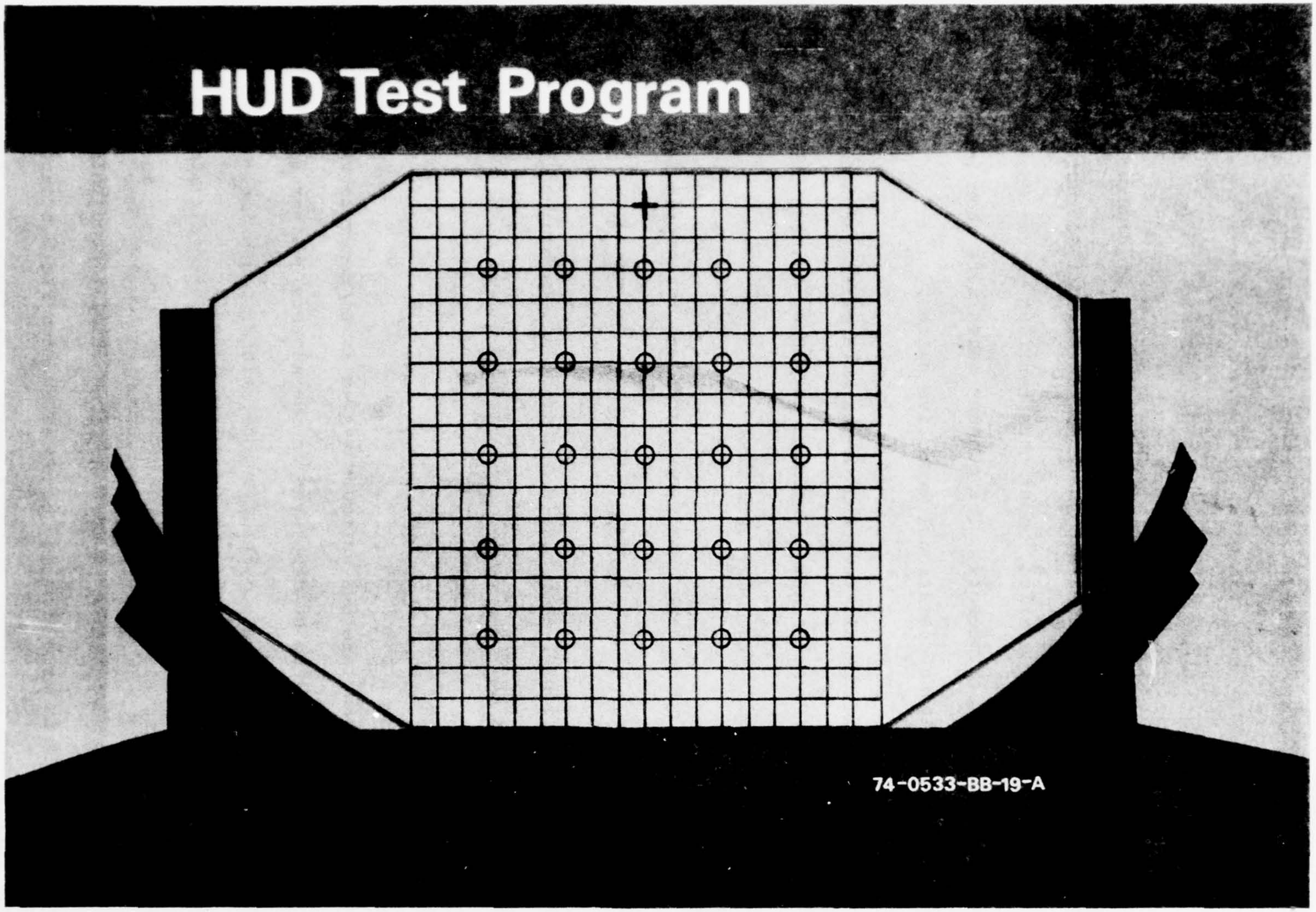

Figure 8. TEST MODES

The gunnery modes, flight tested on the F106 Program by Honeywell, was reprogrammed by Honeywell using the Westinghouse support software package. This package was installed, under this contract on the Honeywell 6080 computer at St. Paul, Minnesota. The gunnery modes were then integrated into the Westinghouse operational executive system.

The missile mode and the air-to-ground modes were extracted from existing weapon delivery systems and integrated into the "Austere HUD" operational program.

In addition, test modes have been implemented and integrated into the operational program.

A complete description of each mode's operation and mechanization can be found in Appendix A8.

2.7 OPERATIONAL SOFTWARE

The purpose of the Austere HUD software system is to generate the suitable symbology required to be displayed on the Austere HUD for five operational modes and a test mode. The five operational modes implemented are air-to-air guns, ALCOSS, air-to-air guns, Tracker, air-to-air missile, air-to-ground manual, and air-to-ground automatic CCIP. The test mode consists of a specific test pattern grid. Specific details concerning the symbology included in each mode may be obtained from the Westinghouse report "F4E Austere HUD Functional Software Symbol Specifications" dated 10 January 1975. See Appendix A4.

System flow is as follows: Aircraft/target environmental data is input from various flight sensors and radar tracking information. Subject to the operational mode currently being processed, this input data is scaled and utilized by computational algorithms to determine the coordinates of each of the positional symbols. All data is then passed to a display package for transformation to display-oriented data which is then output to the HUD. If desired by the pilot or radar officer, a snapshot of all pertinent data utilized during this cycle may be collected on a Raymond Digital Recorder for later playback and analysis.

In order to accomplish the above processes, the Austere HUD software system utilizes the following major sub-programs:

1. System Executive

2. Navigation Panel Sub-Executive

3. Data Input Sub-Executive

4. Mode Algorithms

5. Display Package

6. Snapshot Processing.

General Utility routines used by all of the above routines comprise the remainder of the system. The development of this system, into such a short time span, was made possible by the use of the software modularity concept where sections of existing programs from many systems already in use were integrated into a single package.

2.7.1 System Executive

The system executive routine maintains control and timing of the entire software system execution. It is a cyclic executive keyed to the operational rate of performing all functions at 16 times per second. Thus, the executive is responsible for ensuring that all input, algorithm computations, and display functions necessary for one cycle are performed in their proper order within 62.5 milliseconds. The executive maintains a constant 62.5 millisecond cycle time. If all functions within a cycle are completed in less than 62.5 milliseconds, the executive delays until a total of 62.5 millisecond has elapsed before initiating the functions for the next cycle. If for some reason more than 62.5 milliseconds elapses during a cycle's operations, a warning light is lighted on the navigation panel.

In the meantime, the executive also maintains a check on major code changes requested by the pilot from the ASG-26A switch and sub-mode changes requested by the radar officer from the navigation panel. If a major mode change occurs, the executive interrupts all processing, reconfigures itself for the new mode, and then initiates processing for the new mode. Sub-mode changes are recognized by monitoring flags passed along by the navigation panel sub-executive.

This program represented a new program design necessary to incorporate multi-mode processing control. However, this design incorporates executive design concepts established from previous systems design.

2.7.2 Navigation Panel Sub-Executive

Most system operation controls are contained on the newly installed former navigation control panel. This includes sub-mode, wing span, gun test, and optional display selections. The radar officer also has the ability to change certain values in memory during flight operations. These include re-initializing the number of rounds remaining and selection of air-to-ground manual predefined mission.

Data input and output to the navigation panel is in the form of serial multiplexed data. This serial data must be accessed asynchronously to the system executive basic 62.5 millisecond rate. Thus, a separate navigation panel sub-executive is necessary to process this serial mux data. The basic navigation panel sub-executive utilized by the B-57G system was incorporated into the Austere HUD system. Minor changes were made to decode the input/output data for the new switch representations.

2.7.3 Data Input Sub-Executive

Analog data consisting of 9 AC signals and 16 DC signals must be inputted and scaled once every 62.5 milliseconds. Since these signals are to be processed individually through an A/D converter, a data input sub-executive is necessary to control the access of this data. All data is brought into memory once during a 62.5 millisecond period. However, to save overhead processing time, only the input data required by the particular mode being processed is scaled.

The sub-executive utilized here has been used on many different airborne systems for the Air Force and the Navy. Minor modifications were necessary to control which inputs were scaled for each mode.

2.7.3.1 Mode Algorithms

The computational algorithms for all modes reside in core at all times with processing being controlled by the system executive. These algorithms represent a blend of full fledged solutions to simplified equations necessary only to drive the display. Descriptions of the algorithms follow.

2.7.3.2 Air-to-Air Guns, ALCOSS/Tracer

Honeywell's ALCOSS/Tracer solutions are fully implemented. Since Honeywell considers these programs proprietary, implementation was performed knowing only the inputs desired and the outputs to expect. Westinghouse developed a fast entry-exit technique for program control transferral and assigned specific locations in a global area for passing data to and from the respective programs. Honeywell utilized these concepts in their program per our integration instructions. Thus, system integration only requires a Westinghouse tape to be loaded in the lower 12K of core and a Honeywell tape to be loaded in the upper 4K of core.

2.7.3.3 Air-to-Air Missile

The air-to-air digital missile solution implemented in this system is the long range intercept analog computer solution. This solution is fully implemented and includes the shoot light, hold altitude, and

breakaway commands. In addition to all display functions on the HUD, all standard radar display outputs are implemented. Some additional equations were added to the steering bug computations to scale steering bug movements so that it remains on the screen at all times. These computations do not affect the radar display output.

2.7.3.4 Air-to-Ground, Manual

The computations for this mode are very simple since this is a predefined mission mode. Nine predefined missions consisting of fixed altitudes, air speeds, reticle depression, and dive angles are selected via the navigation panel. The predefined mission can be changed instantaneously without requiring re-initialization of the mode.

2.7.3.5 Air-to-Ground, CCIP (Automatic)

The computations for this mode are a simplified gravity drop in a vacuum solution. Drag coefficients are not utilized since the only requirements for this solution is a relatively realistic display be presented. This solution can be expanded at any time in the future, but does include at this time pipper roll stabilization when the pipper position goes off the display.

2.7.4 Display Package

Data from the algorithms and input data are in real world values, i.e., radians, feet, etc. All positional outputs from the algorithms such as the pipper and velocity vector are in terms of radians or milliradians relative to the ADL. The display package transforms this data

into the five word data blocks necessary for lines, circles, and characters necessary to create the required mode symbology. The data blocks are then transferred to the RAM memory for DMA output to the HUD.

To save overhead time involved with data transfer from memory to the RAM, the entire display buffer in the RAM is preset at mode initialization time. Thus, only words necessary to be modified during normal processing must be output to the RAM.

A subset to the display package is a series of tables and control routines utilized for mode test operations. This control routine is accessed by the system executive when the sub-mode switch is set to mode test. The normal algorithm computations are bypassed and the display drivers are driven directly from the data contained in the tables. These tables define, for each symbol, an initial position, increment of change, time delay between increments of change, and limits on the position of the symbol.

The display package represented a completely new design due to the nature of the Austere HUD and its symbology. However, the design was kept very general in order to allow the insertion or deletion of symbols. Also, this general design is such that this display package could be added to other aircraft systems with only minor modifications.

2.7.5 Snapshot Processing

Data may be collected at any time during a mission by engaging the second detent of the firing mechanism. For each 62.5 millisecond cycle two

system control flags are packed and stored in a large buffer in the RAM. When this buffer becomes filled, it is outputted to the Raymond Tape Recorder for later transcribing to magnetic tape for direct input to a ground based (CDC 6500) computer for analysis purposes.

2.7.6 Core Usage

The following table lists the memory storage utilized by the Austere HUD software system. Storage specified is in decimal. As may be seen from this table, there is room for program expansion since 12K of core is available to the Westinghouse programs and 4K of core is available to the Honeywell algorithms. Note, this is a stand-alone program which has much redundancy that normally would not be used if other weapon modes were added.

	1000 Words
System Executive	0.8
Navigation Panel Sub-Executive	0.6
Data Input Sub-Executive	0.8
Mode Algorithms (Westinghouse)	1.3
Display Package - Display Drivers	0.9
Mode Test Tables	1.0
Snapshot Processing	0.7
General Utility Programs	0.8
Debug Package	0.3
Global Storage	0.3
	7500 of 12000 available
Mode Algorithms (Honeywell)	2000 of 4000 available

2.7.7 System Timing

As has been previously explained, for the system to run at an update rate of 16 times per second; it is necessary that all functions within a cycle including input, algorithms computations display processing, and control must be performed within 62.5 milliseconds. Initially, upon implementation of algorithms, it was found that the cycle time for the air-to-air guns, Tracer mode was much greater than 62.5 milliseconds due to the nature and extent of processing within this particular mode. Thus, modification was made to the system executive and basic mode structure to eliminate all excessive overhead and force the most efficient processing. This modification has been successful and the following table lists the cycle time required for each mode.

Air-to-air guns, ALCOSS	10.7 ms.
Air-to-air guns, Tracer	59.6 ms.
Air-to-air missile	19.0 ms.
Air-to-ground, manual	11.7 ms.
Air-to-ground, CCIP (automatic)	18.5 ms.

2.7.8 General Status as of January 31, 1975

The current status of the Austere HUD software system is that all modes have been implemented and checked out under vigorous static simulator tests. Checkout of the snapshot processing output to the Raymond recorder has not been completed. An interim snapshot program has been implemented and checked out where the data is saved in available memory instead of output to the recorder. Due to memory availability, a limitation

of eight snapshots is software imposed; and a separate engagement of the second detent switch is necessary for each snapshot. Checkout of the recorder output is being performed at this time. Otherwise, the system is undergoing general cleanup of existing coding and implementation of new requested optional display processing. The GFE digital recorder has just arrived at Edwards as of January 24, 1975. Work will proceed to test out the software routines as soon as a missing tape recorder and computer cable can be located in shipping.

2.8 SUPPORT SOFTWARE

The software effort performed during this program is twofold: 1) those efforts related to the Seafac installation, and 2) those efforts in support of the HUD flight tests.

Seafac Software

The work performed associated with the Seafac facility includes the following:

1. Educational assistance to the Air Force.

2. Supply software routines to the Air Force.

3. Provide consultation and assistance to the Air Force.

4. Installation of support software package.

Two programming courses were conducted, one at Wright-Patterson Air Force Base for all interested personnel, and one at the Air Force

Academy for instructors who, in turn, put togethere a graduate level course for the cadets. The course included avionics programming philosophy, how to perform such on an AN/AYK-8, and laboratory exercises.

The software routines supplied to both the Seafac facility and the Air Force Academy installation include a set of utility programs (e.g., SINE, COSINE, SQRT, etc.), peripheral I/O programs (e.g., TTY I/O, analog I/O, etc.), and an assembler which runs on the AN/AYK-8. In addition, a missile firing program was implemented on the Seafac facility which utilizes all its components (e.g., radar, I/O simulator, etc.).

Software consultation and assistance have been provided on an as-needed basis during the course of this effort. This was usually supplied by a telephone conversation, however, occasionally it necessitated a face-to-face meeting. This included assitance to the Air Force/ENA organization's implementation of the dynamic simulator and the Air Force Academy's implementation of their ALCOSS gunnery solution.

The support software package has been made operational on both of Wright-Patterson Air Force Base's CDC-6600's, Edwards Air Force Base's CDC-6500, and the Air Force Academy's B-6700. It should be noted that this facility is being used on a daily basis.

The Air Force people associated with the Seafac facility have, since installation, added routines to the installed software capabilities. They have added many I/O routines (e.g., H-2000 interface) and programmer aids, and have increased the capability of the support software package (crossreference element) at the ASD Seafac facility.

2.9 AN/AYK-8 DESCRIPTION AND CHANGES

A programming manual for the AN/AYK-8 is shown in Appendix A5. The computer is designed from standard electronic modules (SEMS) as shown in figure 9. There are 53 card types consisting of analog and digital building blocks for: the digital computer, serial multiplex type of channels, and analog and digital interface circuitry. Spare space existed in at least one of the LRU's to incorporate the following changes:

1. Add the new HUD serial output channel interface with the TI HUD.

2. Add memory to refresh the HUD continuously so organized as to operate like a DMA access to the memory.

3. Add input/output interface to drive a digital Raymond Tape Handler in order to get digital instrumentation on board the aircraft in addition to the analog instrumentation in the McDonnell-Douglas modification.

4. Modifications to adapt the AN/AYK-8 interface to the F4E aircraft.

5. Necessary wiring change to adapt the computer signals to the F4 aircraft wiring modifications.

A complete thermal analysis and vibration analysis was performed to assure flight safety conditions. Appendix A6 is a report of the

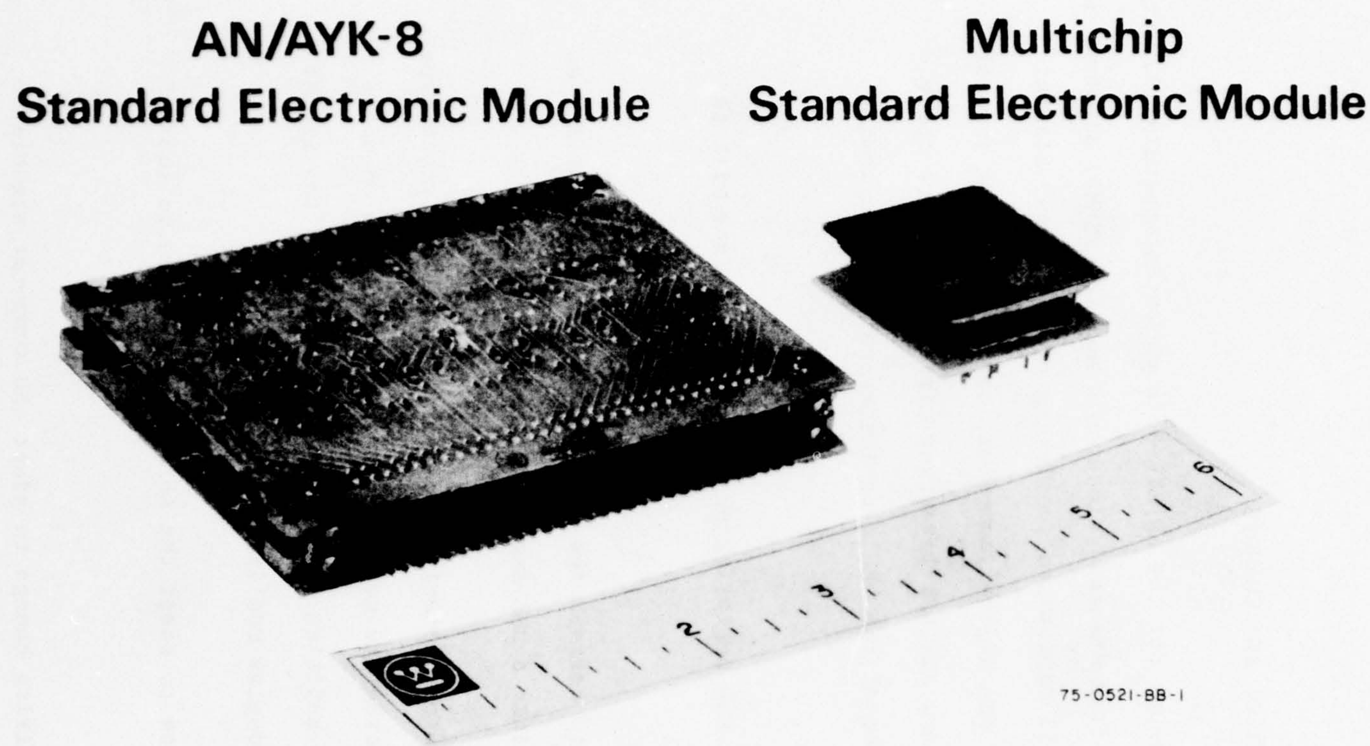

Figure 9. WESTINGHOUSE STANDARD ELECTRONIC MODULE

thermal test conducted at Edwards Air Force Base. Two duplicate computers were modified for use at Edwards Air Force Base. One computer was modified for an Air Force application in the F106 at Tyndall Air Force Base (referred to in this report and contract as the Honeywell computer) and a fourth computer was modified to become the dynamic simulator at Seafac. All of these units have been modified, tested out, and put into operation; except for the Tyndall unit which was delivered to Seafac in an operational status.

2.10 AGE AND GROUND SUPPORT EQUIPMENT

Two surplus GFE AN/AYK-8 computer test benches were modified on this contract. Cabling equivalent to the F4 Class II modifications were generated for the two benches. One bench was sent to Dayton/Seafac operation and the second bench was sent to Edwards Air Force Base to support the F4 flight test. A static simulator was developed for Edwards Air Force Base because the Seafac Simulator generated on this program was not available to be also used at Edwards Air Force Base (it is in continuous use at Seafac on other programs). Figure 10 is a picture of the bench plus the static simulator, plus the ODU unit of the Austere/HUD. Figure 11 is a closeup of the static simulator which was put into operation at Edwards Air Force Base, after passing through Seafac tests. Two GFE surplus consoles had to be refurbished for software debugging for the AN/AYK-8 computer on this contract for the F4E Austere/HUD program in addition to the console refurbished for the Seafac portion. The Seafac usage of consoles was such that a console was not available for use at Edwards Air Force Base. Westinghouse provided one of these consoles

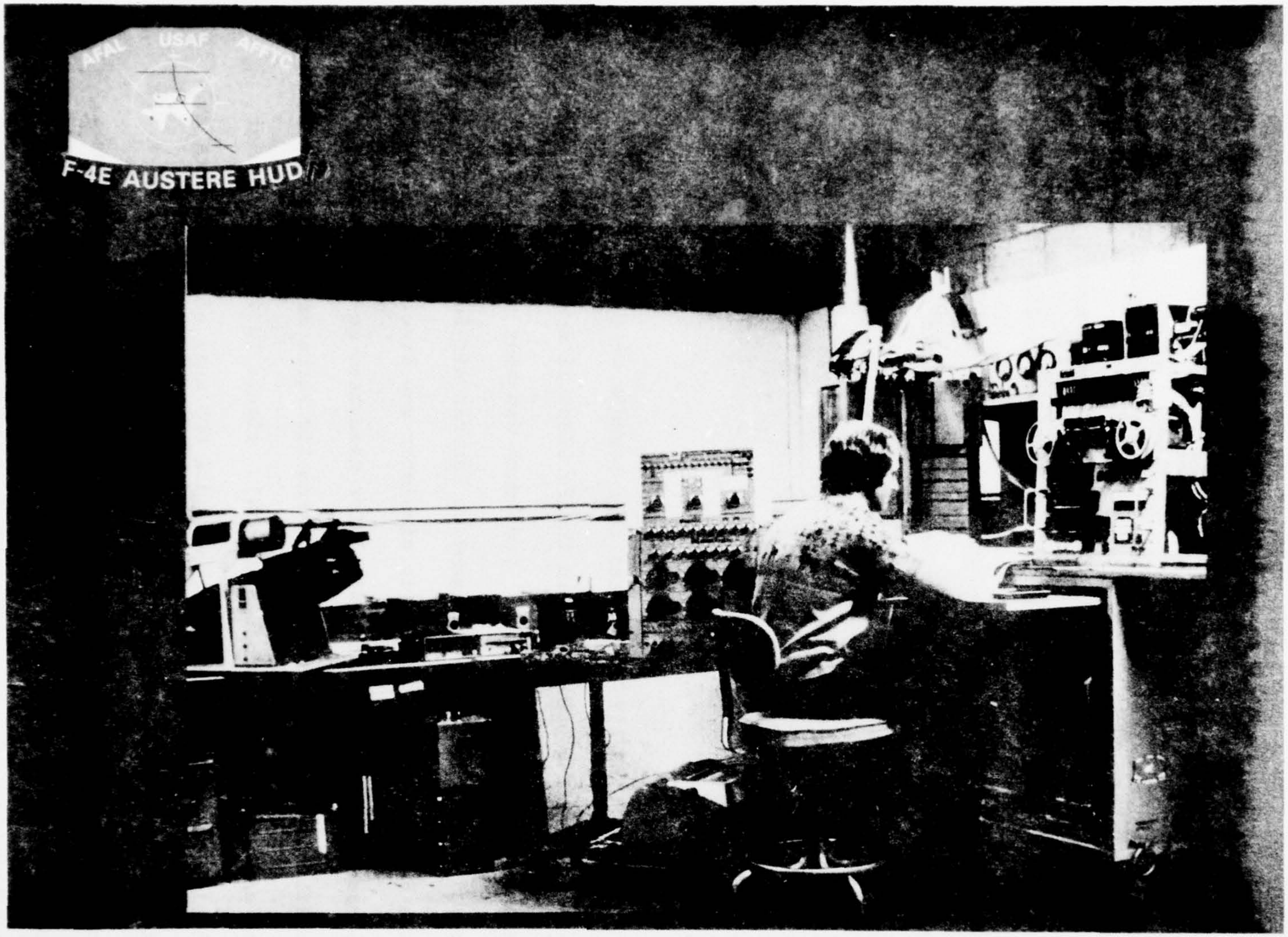

Figure 10. THE HOT BENCH AT AFFTC.

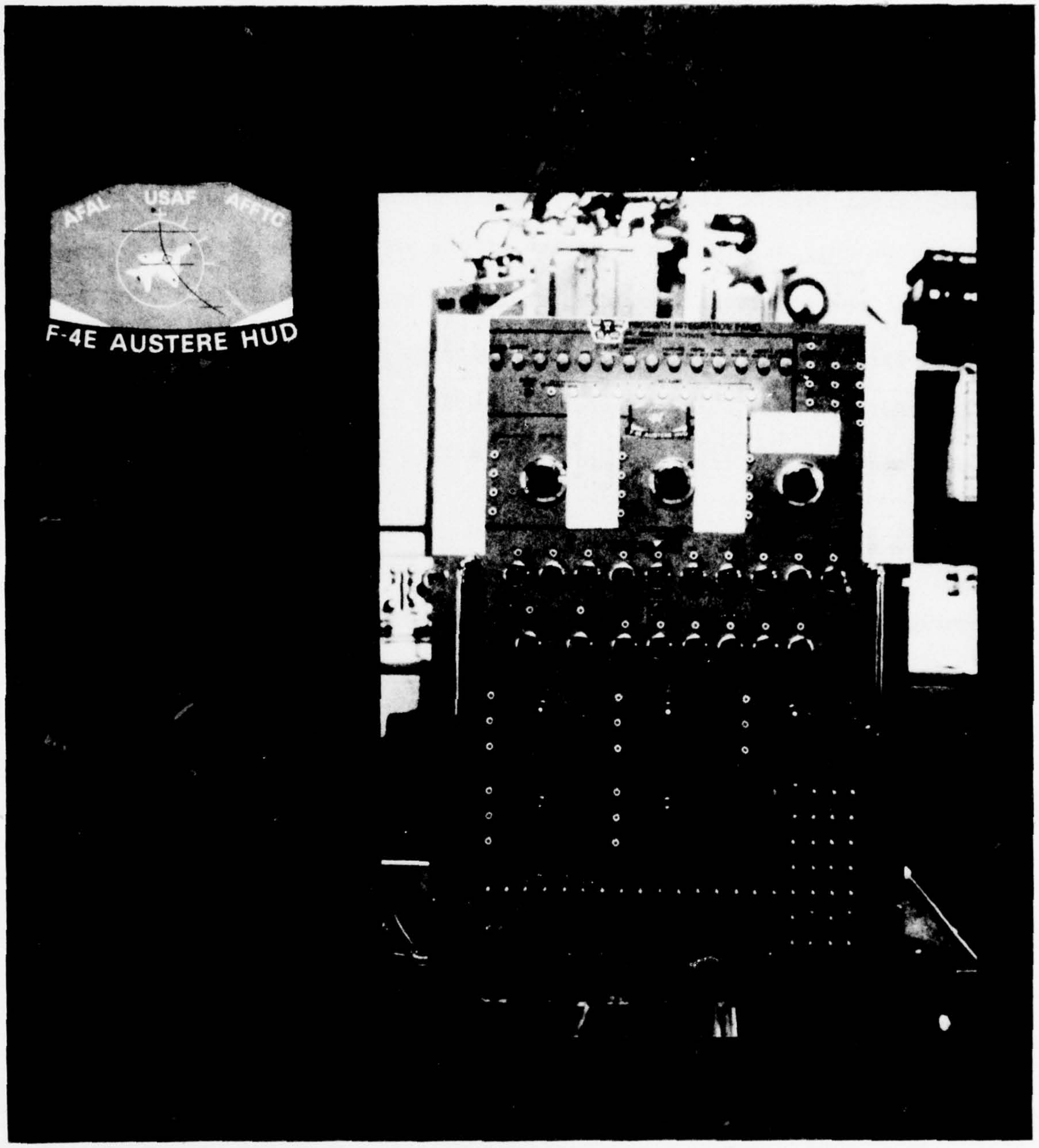

Figure 11. STATIC AIRCRAFT SIMULATOR USED ON THE HOT BENCH AT AFFTC.

for use at Edwards Air Force Base on a loan to the Air Force basis. The Raymond mechanical tape handler is also a Westinghouse loan to the Air Force for use on this program for a period of one year from date of contract. Many of the additional required standard cards were GFE from Government surplus B57-G stock. All of the AGE equipment was put into operation and is performing reliably at all places including the Air Force Academy installation mentioned in the first portion of this report.

2.11 INTEGRATION

A complete ground integration/validation test plan was generated by Westinghouse and approved by the Air Force for use at Seafac. Appendix A7 is the test plan. A successful demonstration at Seafac was arranged by the Air Force to show the HUD in operation in Dayton during the fall of 1974. The equipment was then shipped out to Edwards Air Force Base and re-integrated and tested on the ground AGE. The system was then installed in the aircraft and all of the test modes were duplicated. At this time, January 1975, flight tests have not been performed because of various aircraft mechanical problem delays.

2.12 EDWARDS AIR FORCE BASE FLIGHT TEST CENTER OPERATIONS STATUS

As of the date of this interim report (January 30, 1975), all hardware and software was ready for flight tests. One remaining problem for which a cause has been found is that the test gyro package is loaded beyond expectations, and consequently is out of calibration. The cause turned out to be several old B57-G inputs were also connected to this signal. These have since been disconnected and appropriate documentation changes noted.

A second problem remaining is finding a suitable source of magnetic tape to paper tape reduction at the Air Force Flight Test Center. The presently used 10 character per second paper tape reduction unit is too slow and not very reliable. Tapes are being generated at Westinghouse-Baltimore or at Seafac to compensate for this problem temporarily.

2.13 COST ANALYSIS FOR HUD INSTALLATION IN F4E

Westinghouse is obligated to establish a baseline APQ-120 LRU-1 computer and interface coverage to Air Force Avionics Lab's approval as specified in the work statement Amendment no. 1, page 9 of 10 pages.

A meeting was held at Dayton in October during which approval for the baseline was given and the guidelines for the improvement coverages were given. This report summarizes the study results for cost estimates to modify the aircraft to the specified customer provided configurations. All improvements are retrofit in line changes at any point in the proposed LRU-1 baseline production cycle.

The Air Force approved baseline coverage for the APQ-120 LRU-1 computer and interface unit for ACM weapon modifications is specified in figure 12.

2.13.1 Baseline

The improvements resulting for the baseline addition is dogfight mode capability for present missile inventory of the F-4E aircraft, plus addition of 7F and 9L improvements. The guidelines given to Westinghouse

BASELINE

CP1205 - F4J Production Hardware

- G.P. Digital Computer
- Memory Size 8192 Words → 16,384
- Word Length 16 Bits
- Speed 250 - 300 kops/sec
- Interface
  - Connect Existing F-4E Sensors/Weapons/Controls
  - Simple Link to 101
  - Simple Link to Future HUD
- Physical Constraints
  - Maintain Geometry
  - Live with Existing Environment

Figure 12

by the Air Force Avionics Lab at the October meeting for the improvement combinations are as specified in figure 13.

Each case will be presented with the assumptions and the impact conditions; the cost exercises for the various cases is included in a separate package attachment to the report.

2.13.2 Case 1

Add the Austere HUD to the 101 Aircraft

Figure 14 gives the assumptions.

- Case 1

  Addition of Austere HUD only

  - 101 Aircraft
  - Non-101 Aircraft

- Case 2

  Addition of Austere HUD/Gunsights

  - 101 Aircraft
  - Non-101 Aircraft

- Case 3

  Addition of Air Combat Evaluator to Case 2

- Case 4

  Addition of Low Cost Air-to-Ground Mode to Case 3

Figure 13.

Assumptions

- LRU-1 Drives TI Austere HUD
- 101 Has Matching Two-Way Serial Channel
- All Air-to-Ground Functions Performed in 101
- All Air-to-Ground Switchology Performed by 101
- 101 Installs LRU-1 to 101 Serial Link Aircraft Wiring
- LRU-1 Does Air-to-Air Missiles
- Air-to-Air Guns Reestablished

Figure 14.

Figure 15 gives the impact in the various different areas for the aircraft modifications.

Impact

- LRU-1
  - Add 8K Words Memory
  - Modify Present HUD Serial Link
  - Software Changes
  - AGE Changes
  - 6 AC, DC, 6 Discretes I/O
- LRU Changes
  - Replace ASG-26 ODU with Austere HUD
- Aircraft Wiring
  - Add Serial Link to Austere HUD
- Documentation
- Qualification
- Flight Tests

Figure 15.

2.13.2.1 Addition of Austere/HUD to Non-101 Aircraft

Figure 16 gives the assumptions for this particular case and figure 17 gives the impact.

Assumptions

- LRU-1 Drives HUD
- Retain ASQ-91 for Air-to-Ground Functions
- LRU-1 Does Missile Computations
- Air-to-Air Guns Reestablished

Figure 16

Impact

- LRU-1
  - Use Remaining 500 Words of Original 8K Words
  - Modify HUD Serial Link
  - Software Changes
  - AGE Changes
  - Add 10 AC Inputs and DC Input
  - Add 12 Discrete Inputs
- LRU Changes
  - Replace ASG-26 with Austere HUD
- Switchology
- Aircraft Wiring
  - See Figure 16
- Documentation
- Qualification
- Flight Test

Figure 17

2.13.3 Case 2

2.13.3.1 Addition of Austere/HUD Plus Gunnery Weapon Modes to the 101 Aircraft

Figure 18 gives the assumptions and figure 19 gives the impact.

Assumptions

- LRU-1 Drives HUD
- 101 Has Two-way Serial Channel to LRU-1
- All Air-to-Ground Functions Performed in 101 System
- All Air-to-Ground Switchology Performed by 101 System
- ALCOSS/Tracer Gunnery Routine Additions in LRU-1
- Flight Control Gyros/Accelerometers Sufficiently Accurate for Rates and Accelerations.

Figure 18.

Impact

- LRU-1
  - Add 8K Words Memory
  - Modify HUD Link
  - Software Changes
  - AGE
  - Add 9 AC Signal Inputs
  - Add 4 Discretes
- LRU Changes
  - Replace ASG-26 with Austere HUD
  - Modify Flight Control LRU for Reference Access
  - Use AJB7 for Acceleration Value
- Aircraft Wiring
  - Add Link to Austere HUD
  - Assume Link to 101 Installed on 101 Program
  - Add in 15 Wires Flight Controls and AJB7 to LRU-1
- Switchology
  - Assumes 101 Provides for Air-to-Ground Mode Selection Controls
- Documentation
- Qualification
- Flight Tests

Figure 19.

2.13.3.2 Addition of Austere/HUD Plus Gunnery Weapons Modes to the Non-101 Aircraft

Figure 20 gives the assumptions and figure 21 gives the impact for this case. Figure 22 is the aircraft modifications impact.

Assumptions

- LRU-1 HUD
- Retain ASQ-91 for Air-to-Ground Functions
- ALCOSS/Tracer Gunnery Routine Additions
- Flight Control Gyros Sufficiently Accurate for Rates and Accelerations

Figure 20.

Impact

- LRU-1
  - Add 8K Words Memory
  - Modify HUD Serial Link
  - Software Changes
  - AGE
  - Add 12 AC Inputs
  - Add 10 Discrete Inputs
- LRU Changes
  - Replace ASG-26 with Austere HUD
  - Modify Flight Control Amplifier Reference
  - ABJ7 Operation Status
- Switchology
- Aircraft Wiring
  - See Figure 22
- Documentation
- Qualification
- Flight Tests

Figure 21.

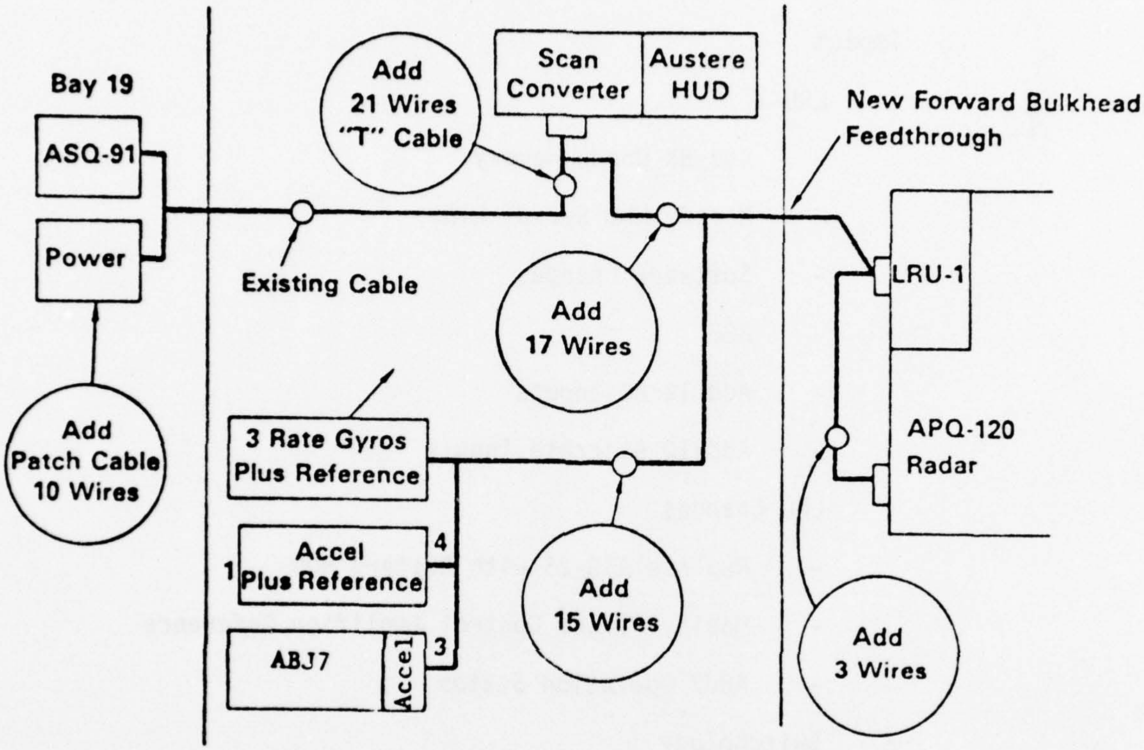

Figure 22. Case 2. Non-101 Aircraft HUD/Gunsights Aircraft Wiring Impact

2.13.4 <u>Case 3</u>

2.13.4.1 Addition of Austere/HUD Plus the Gunnery Weapons Modes Plus the Air Combat Evaluator Mechanizations

Figure 23 gives the assumptions; figure 24 gives the impact for this case.

Assumptions

- Same as Case 2
- ACE Routine Addition to LRU-1

Figure 23.

Impact

- LRU-1
  - Same as Case 2
  - Add 2 DC Radar Error Signal Inputs
- LRU Changes
  - Replace ASG-26 with Austere HUD
  - Modify Flight Control LRU for Reference Availability
  - APQ-120 Radar Mods
- Aircraft Wiring
  - Add Link to Austere HUD
  - Assume Link to 101 Installed on 101 Program
  - Add in 15 Wires Flight Controls to LRU-1
- Switchology
  - Assumes 101 Provides for Mode Selection Controls
- Documentation
- Qualification
- Flight Tests

Figure 24.

2.13.4.2 Addition of Austere/HUD Plus the Gunnery Weapons Modes Plus the Air Combat Evaluator Mechanizations for Non-101 Aircraft

Figure 25 gives the assumptions; figure 26 gives the impact and figure 27 is the symbolic representation of the aircraft cable modifications.

Assumptions

- Same as Case 2
- Retain ASQ-91 for Air-to-Ground Functions
- ACE Routine Addition to LRU-1

Figure 25

Impact

- LRU-1
  - Same as Case 2
  - Add 14 AC Inputs
  - Add 10 Discrete Inputs
- LRU Changes
  - Same as Case 2
  - Modify APQ-120
- Switchology
  - Need ACE Control Switch
- Aircraft Wiring
  - See Figure 27
- Documentation
- Qualification
- Flight Tests

Figure 26.

2.13.5 Case 4

2.13.5.1 Addition to Previous Cases of Air-to-Ground Modes added to LRU-1 Configurations

In this case, two modes of aided visual air-to-ground modes are added as follows:

1. Impact-oriented manual release.
2. Target-oriented automatic release.

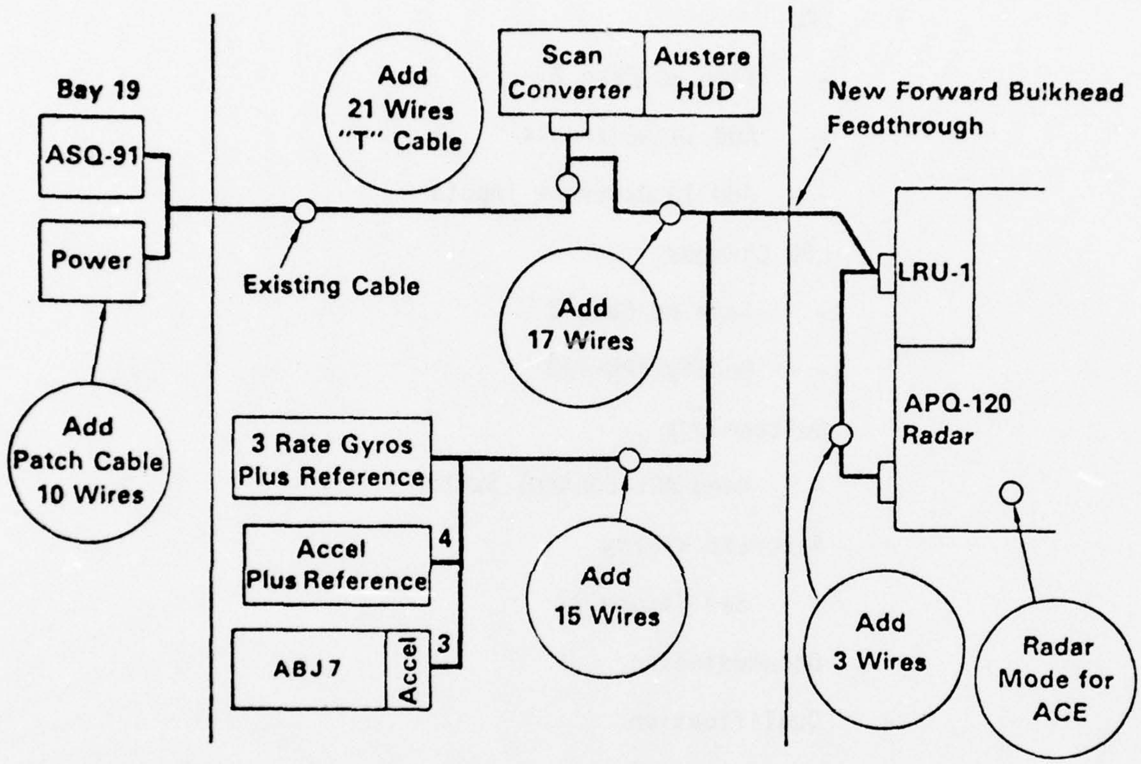

Figure 27. AIRCRAFT WIRING IMPACT

Figure 28 gives the assumptions and figure 29 gives the impact. Figure 30 gives the aircraft wiring impact.

In terms of time schedules, figure 31 gives the baseline contemplated, and the suggested schedule for Austere HUD addition to the F4E aircraft.

The second part of figure 31 gives the worst case time schedule for implementing any of the previous cases. Some limitations are that initial go ahead is required in the third quarter of Calendar Year 75 and production

Addition of Case 2 and Case 3 with Simple LRU-1 Air-to-Ground Modes (Serial Link).

- Assumptions
  - LRU-1 Drives HUD
  - Replace ASQ-91 with Remote Multiplex Terminal in Bay 19
  - Use 101 Serial Channel to Communicate to Bay 19 Mux Terminal
  - Make New 91 Backseat Panel
  - Maintain Pave Spike Mode
  - ALCOSS/Tracer Gunnery Routine Addition Case 2
    Case 3
  - ACE Routine Addition
  - Radar Modifications
  - Documentation
  - Qualification
  - Flight Tests

Figure 28.

go ahead is required in the first quarter of Calendar Year 77 if some commonality of aircraft modification coverage is to be maintained during the modification process.

The estimated cost projections resulting from this study were given in a report to the Air Force.

Impact - Non-101 Birds

- LRU-1
  - Add 8K Words Memory
  - Modify HUD Serial Link
  - Software Changes
  - AGE
  - Radar Drive Mod
- LRU Changes
  - Add Bay 19 Terminal in 91 Location
  - Replace All ASG-26 Units
  - Add R.O. Control Panel
  - Remove ASQ-91
  - Add New HUD
  - Modify Flight Control Amplifiers Reference
  - ABJ7 Operation Status
- Aircraft Wiring Changes
  - See Figure 30
- Switchology
  - Make New ASQ-91 - R.O. Panel
- Radar Modifications
- Documentations
- Qualification
- Flight Tests

Figure 29.

Case 4. Aircraft Wiring Impact
Case 2 Plus Case 3 Plus Air-to-Ground Mode Serial Link

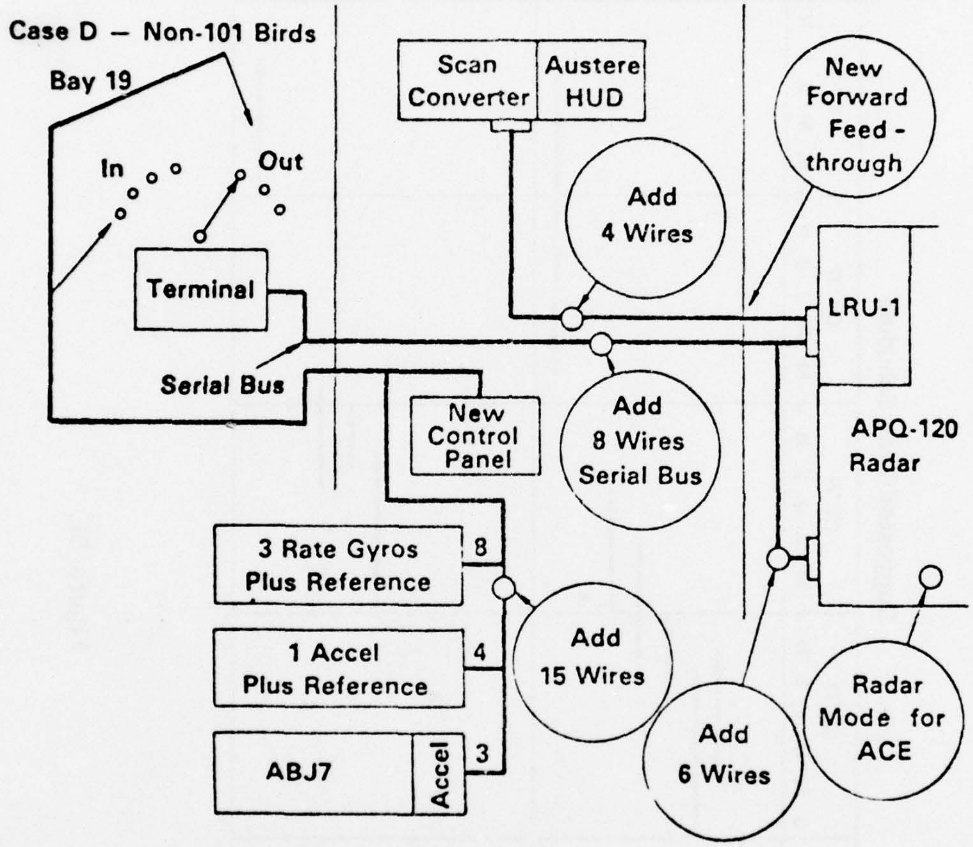

Figure 30.

Significant improvements to the present F-4E gunnery modes and air-to-ground modes can be gained by addition of a better pilot heads-up display and mechanization. The Austere HUD is one of the means of accomplishing this improvement.

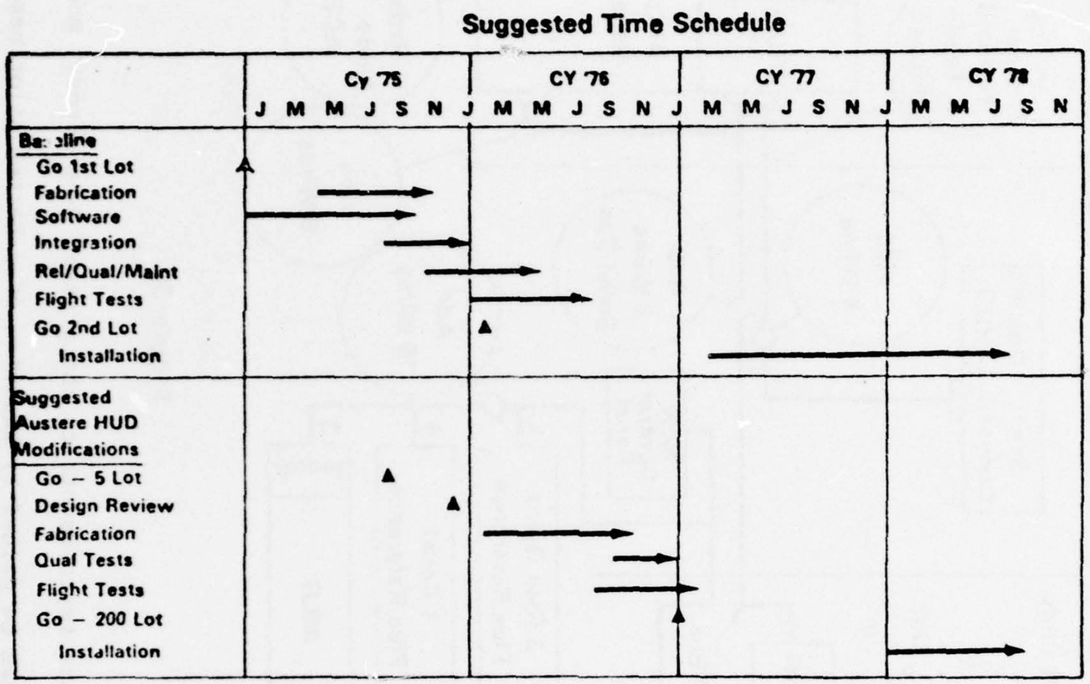
Suggested Time Schedule
Cy 75
CY 76
CY 77
CY 78
J M M J S N
Baseline
Go 1st Lot
Fabrication
Software
Integration
Rel/Qual/Maint
Flight Tests
Go 2nd Lot
Installation
Suggested Austere HUD Modifications
Go – 5 Lot
Design Review
Fabrication
Qual Tests
Flight Tests
Go – 200 Lot
Installation

Figure 31.

SECTION III
CONTRACT DATA REQUIREMENTS

The contract calls for delivery of a number of data items as follows:

3.1 SEQUENCE NUMBER A001

Programmers' Manual and Software Course Materials.

Copies of AN/AYK-8 Programmers' Manual, Programmers' pocket plastic-protected instruction format coards, and general assignments were distributed to AF/ASD Seafac personnel, and AFFTC personnel. This item is considered closed.

3.2 SEQUENCE ITEM A002 - SOFTWARE USER'S MANUAL

Support software users' manual, a manual of instruction sheets and master card files were delivered to Seafac at AF/ASD, Building 485, the Air Force Academy, and Edwards Flight Test Center. This items is considered closed.

3.3 SEQUENCE ITEM A003

Abstract of New Technology (ANT) and Flight Safety Certification.

A Flight Safety Analysis Report was submitted for Project approval in August 1974.

This report became Appendix E of the Class II Mod Kit. A copy of the report is included in this report as Appendix A3. Copies of the of the McDonnell-Douglas Company Single Point Analysis Report (Appendix G of Class II Mod Kit) is not included because of excessive size. Copies can be found at AFFTC in the Class II Mod Kit. This item is considered closed.

3.4 SEQUENCE NUMBER A004 - INTERFACE CONTROL DOCUMENT

This document was generated, submitted for project approval in July and successfully used by Westinghouse and TI to design/test the computer/HUD serial link. Appendix A1, AN/AYK-8 Output Channel Interface with TI HUD is a copy of this documentation item. This item is considered closed.

3.5 SEQUENCE NUMBER A005 - DIGITAL COMPUTER PROGRAM DEFINITION

A complete report was prepared and submitted to the project for approval in the Fall of 1974. The project programmers used this report to generate the software from the program requirements.

Appendix A4 (F4E Austere HUD Function Software Symbol Specification) dated January 10, 1975, is a copy of the updated F4E HUD digital computer program requirements list. This item is considered closed.

3.6 SEQUENCE NUMBER A006 - PRODUCTION CONFIGURATION DEFINITION

A study was made of the various aircraft configurations and mode capabilities as defined by the project office at project meetings at Wright-Patterson Air Force Base. A summary of the baseline configuration,

four different cases, assumptions and conditions are part of this report (Section 2.13). The baselines and assumed cases for the study was approved by the Air Force Project Office. The costs are included in this report as a separate attachement item for control of distribution by the Air Force Project Office.

3.7 SEQUENCE NUMBER A007 - TECHNICAL REPORT, FINAL

This item covers all data specified and is the Final Report. This report was submitted along with item A009 (Para. 3.9). Requirements of SOW, para. 4.8, were satisfied by a formal presentation at Nellis AFB of technical information and costs for LRU-1. This subject is in text of paragraph 2.13 of this report. This item is now considered closed.

3.8 SEQUENCE NUMBER A008 - R&D STATUS REPORT

These reports were submitted monthly. Appendix A1 contains summary data on this subject. This item is considered closed.

3.9 SEQUENCE NUMBER A009

Technical Report fo Flight Test Analysis - Final Report. An interim report for F-4E Austere/HUD Program, Radar Modification, Phase D was submitted and approved with revisions in the Fall of 1975. This report is Appendix A9 of this combined report. This item is considered closed.

SECTION IV

SUMMARY OF STATUS/DISPOSITION OF GFE EQUIPMENT UNDER THIS CONTRACT

In order to minimize cost on this contract, the Air Force made use of surplus digital computer, surplus modular standard electronic modules used on the Tropic Moon III Program (B-57G) and SADRAM (F4D) Program, surplus AGE equipment, surplus spares, proven support software routines, proven operational executive software routines, and software functional subroutines. In addition, the Air Force Project Office arranged to borrow Westinghouse's instrumentation and computer console, borrow a Navy (Pt. Mugu, California) computer console, and collect GFE factory test equipment for future equipment refurbishment, provide test equipment to support Edwards AFFTC and supply Seafac and Avionics Laboratories with up-to-date laboratory equipment. Perhaps the most significant cost saving item the Air Force Project chose to use was the use of existing on-base/site powerful ground based computers at ASD, Wright-Patterson AFB, Edwards AFFTC, AFA, Westinghouse Defense Center and Honeywell-Minneapolis, to automatically generate the programs and configuration control for all of the software used in all phases of Seafac and the F4E Austere HUD program. At any one of these places (Dayton, Minneapolis, Baltimore, Palmdale, California), an exact flight computer tape and software configuration control listing can be generated for this program.

4.1 Flight control LUR's could not be delivered from Hill AFB on time to meet contract needs; therefore the request was cancelled as follows:

Westinghouse RGP #2980 of July 8, 1974 (Items 1 - 7)

Item	Quantity	Description	Delivery/Location
6615 944 1799	(1) One each	Part No. 230E420G2A, Amplifier Assy. AN/ASA-32 Control, C-6563/ASA-32H Ref 1F-4E-4, Figure 4-57-37.	(Did not receive)
6615 796 1466	(2) Two each	Part No. 197C326G2, Gyro, Pitch Rate, CN-560/ASA-32 Ref. 1F-4E-4, Figure 4-27-20-25.	(Did not receive)
6615 794 6285	(3) One each	Part No. 107C325G2, Gyro Yaw Rate, CN-559/ASA-32 Ref 1F-4E-4-4, Figure 4-47-20-27.	(Did not receive)
6615 796 1467	(4) One each	Part No. 197C324G3, Gyro Roll Rate, CN-558/ASA-32 Ref 1F-4E-4-4, Figure data not available.	(Did not receive)
6615 600 0969	(5) One each	Part No. 197C282G3, Lateral Accelerometer, MX-3421/ASA-32D Ref 1F-4E-4-4, Figure 4-57-60.	(Did not receive)
6615 758 2477	(6) One each	Part No. 756D180G1, Electrical Equipment Rack, MT-2463/ASA Ref 1F-4E-4-4, Figure 4-57-39.	(Did not receive)
Old Not Convert	(7) Three each	Part No. MX-6663/AJB-7 Accelerometer, Aircraft Ref 1F-4E-4-4, Figure 4-47-20-22.	(Did not receive)

4.2 Factory test sets were delivered and used on this contract. The equipment is all at Westinghouse-Baltimore (East Building) except for the following equipment which is being used at the Air Force Flight Test Center:

1 - Scope

1 - Power Supply

1 - Power Supply

1 - Power Supply

1 - Power Supply

1 - Digital Voltmeter.

Upon completion of the Air Force Flight Test Center's flight schedule, the equipment is to be returned to the factory test sets.

Westinghouse RGP #2980 (Items 8 - 13)

Quantity	Description	Delivery/Location
(8) One each	Servo Composite T/S #424 S/N 001 TFB 8428 CA1064.	Westinghouse - Bay 13
(9) Two consoles	Computer Composite T/S #442 S/N 001 TFB 8433	Westinghouse - Bay 13
(10) One each	Computer Memory T/S #439 S/N 001 TFB 8430 CA 0969	Westinghouse - Bay 11
(11) One each	Computer Processor T/S #440 S/N 001 TFB 8431 CA 1052	Westinghouse - Bay 11
(12) One each	Computer I/O T/S #441 S/N 002 TFB 8434 CA 1066	Westinghouse - Bay 13
(13) One each	Computer P/C Board T/S #428 S/N 003 TFB 8423 CA 1076	Westinghouse - Bay 13

4.3 The flight test equipment is as follows:

Westinghouse RGP #2980 (Items 14 - 33)

Item	Qty.	Description	Delivery/Location
14	1	Memory/Power Supply, P/N 616R487G06, S/N A1015, LRU-27	SEAFAC (W-P AFB)
15	1	Memory/Power Supply, P/N 616R487G06 S/N A1013, LRU-27	AFFTC/Hot Bench (Edwards AFB)
16	1	Processor/I/O, P/N 616R501G012, S/N A1016, LRU-28	SEAFAC (W-P AFB) Dynamic Simulator
17	1	Processor/I/O, P/N 616R501G012, S/N A1001, LRU-28	SEAFAC (W-P AFB)
18	1	I/O Power Supply, P/N 616R525G017, S/N A1019, LRU-29	SEAFAC (W-P AFB)
19	1	I/O Power Supply, P/N 616R525G012 S/N A1101, LRU-29	SEAFAC (W-P AFB)
20	1	Computer/Nav Panel, P/N 1000 E24G07, S/N 0021, LRU-305	Westinghouse-Baltimore (Used for parts)
21	1	Computer/Nav Panel, P/N 1000 E24G06, S/N 0020, LRU-305	AFFTC/Bench (Edwards AFB)
22	1	Computer Mount, P/N 616R769G01 S/N A1006, LRU --	Westinghouse- Bay 13
23	1	Computer Mount, P/N 616R769G01 S/N A1011, LRU --	Westinghouse- Bay 11
24	1	Cable Assy., P/N 5995-ND-096-426L, P/N N/A, LRU --	SEAFAC (W-P AFB)
25	1	Memory Power Supply, P/N 616R487G12 P/N A1021, LRU-27	SEAFAC (W-P AFB)
26	1	Processor/I/O, P/N 616R501G12, S/N A1002, LRU-28	SEAFAC (W-P AFB)
27	1	I/O/Power Supply, P/N 616R525G15, S/N A1018, LRU-29	AFFTC/AC (Edwards AFB)
28	1	Computer AGE Bench, minus exterior power cables (60 Hz, 115 VAC; 400 Hz, 115 VAC, 28 VDC)	AFFTC (Edwards AFB)

Item	Qty.	Description	Delivery/Location
29	1	B57G AYK-8 Computer	Bench at Edwards AFB
30	1	Power Supply and Memory, P/N 616R487G06, S/N A1025	AFFTC (Edwards AFB)
31	1	LRU-28 - I/O Processor, P/N 616R501G0 , S/N A1022A	AFFTC (Edwards AFB)
32	1	LRU-29 - Input/Output Unit, P/N 616R525G017, S/N A1011	AFFTC (Edwards AFB)
33	1	B57G AYK-8 Computer Nav Panel, P/N 1000E24G07, S/N 0019	AFFTC (Edwards AFB)

APPENDIX A1

AN/AYK-8 OUTPUT CHANNEL WITH T. I. HUD

SPECIFICATION NUMBER

REV LTR	DATE	REVISION NOTICE NUMBER	PAGES AFFECTED	APPROVED
B	6/20/74		8	[illegible]
A	[illegible]/21/74		1, 2, 3, 11	[illegible]

REVISIONS

ORIGINALLY PREPARED FOR CONTRACT NO.	**Westinghouse Electric Corporation** AEROSPACE DIVISION BALTIMORE, MD., U.S.A.
ORIGINATOR W. Miller W. Miller	TITLE AN/AYK-? OUTPUT CHANNEL INTERFACE WITH T.I. HUD
PAGE 1 OF 16 PAGES	SPECIFICATION TYPE / CODE IDENT. NO. 97942 / SPECIFICATION NUMBER

BA 5656-1

1.0 SCOPE

This specification defines required modifications to the input-output channel interface of the AN/AYK-8 computer, and the data formats for interfacing with the Texas Instruments Heads Up Display.

2.0 SERIAL DATA CHANNEL DESCRIPTION

The AN/AYK-8 serial data channel will be used to transfer symbol information generated by the computer software programs to the HUD electronics unit. A simplex data link structure provides transfer of display information in a word serial, bit serial format. The initiation of transfer will be the responsibility of the HUD terminal. A total of 81 bits, organized into 5, 16-bit words and a parity bit will be transmitted per request. The HUD terminal will have the responsibility of performing a parity check on the received data. The decision to reject or utilize the data in the event of parity failure will also be the responsibility of the HUD system.

2.1 Signal Functions. The interface will consist of four signals (figure 1) the request, clock, enable and data signals.

2.1.1 Request Signal. The request signal will be generated asynchronously by the HUD terminal and will initiate transmission over the interface. Except for initialization, section 9, transmission from the AN/AYK-8 will start from 2 to 10 microseconds from the leading edge of the request signal. The request signal will be reset by the HUD terminal on the first positive edge of the clock signal following the enable signal, figure 2.

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2.1.2 Clock Signal - The interface clock shall be generated by the AN/AYK-8 computer and shall be continually applied to the interface. The clock signal shall be a 1 mHz plus or minus 1 percent with 40% duty cycle.

The AN/AYK-8 will utilize the negative going clock for shifting information and the HUD will shift on the positive going edge to eliminate skew effects between clock and data.

2.1.3 Enable Signals. The enable signal shall indicate data is being transmitted over the interface. Regardless of the message category the enable signal will go to a logical 1 state on the leading edge of the first data bit and will be modified to remain high until the trailing edge of bit 81 or the parity bit. At the transmit terminal, the leading edge of the enable signal shall coincide to within plus or minus 100 nanoseconds of the negative going edge of the clock signal.

2.1.4 Data Signal. The data line will carry the information to the HUD system.

2.2 Coding. For data transmission, the interface shall utilize dual rail (true/complement), NRZ coding format.

2.3 Data Rate. The data bit rate shall be a 1 megabit per second plus or minus 1 percent.

2.4 Message Length. Each transmission initiated by the request signal will consist of 5, 16-bit words plus a parity bit. Word one is transmitted first followed by words 2, 3, 4 and 5 in that order, figure 3. The most significant bit (MSB) of each word is transmitted first. The least significant bit of each word is immediately followed

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by the most significant bit of the following word. The parity bit will immediately follow the LSB of word 5.

The information composition of the five words will depend upon the message type as specified in section 6. However, for words or portion of words not utilized or not assigned specific functions (the not used words of the formats in section 6) will have "don't care" values.

2.5 Parity. One parity check will be made on all five words or 80 bits transmitted. During transmission the parity bit shall be assigned a value so that the total number of ones in the transmitted message is odd. During reception, the parity bit shall be checked by determining whether or not the received word contains an odd number of ones. It will be the responsibility of the HUD terminal to use or reject the message which has failed a parity check.

2.6 Voltage Level Definitions. For all four signals a logical one at the transmitter inputs will be indicated by a voltage level greater than 2.4 volts and a logic zero by a voltage level less than .5 volts. However, at the receiver output a logical one is represented by a voltage level less than .5 volts and a logical zero by voltage level greater than 2.4 volts. The logical one and logical zero state times will be one microsecond plus or minus 100 nanoseconds.

3.0 <u>TRANSMISSION LINES</u>

Each interface signal shall be transmitted by a dedicated cable.

3.1 Cable Types. Each cable will be a two-conductor twisted, shielded jacketed cable.

3.2 Grounding Approach. Each individual cable shield will be grounded to chassis ground at the transmit end only. The four cables will be grouped together and the group of four cables surrounded by a second shield. This shield will be ground to chassis ground at both ends.

4.0 LINE TRANSMITTERS

Each line driver will be 9614 or equivalent TTL compatible dual differential line transmitters supplying both true and complement signals. The transmitters will have a 39 ohm series resistors in the outputs as shown in figure 4. The transmitter will be capable of operating from -55 to +70°C. Each transmitter will operate from a 5 volt source drawing about 50 ma. Other characteristics of the transmitters are summarized as follows.

4.1 Output Circuit Voltage. A logical one will be indicated by a minimum voltage of 2.5 volts as measured at the output of the 9614 circuit. A logical zero will be no greater than .5 volts also measured at the output of the 9614 circuit.

4.2 Rise and Fall Times. The rise and fall times of the signal shall be less than 100 nanoseconds when measured at the 10 percent and 90 percent of the nominal voltage levels. The measurement will be made across the 2.2K ohm resistor at the receiving terminals.

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5.0 INPUT CIRCUIT CHARACTERISTICS

Each receiver will be 9615 units or equivalent dual differential line receiver. The line receivers will be shunted with a 2.2 K ohm resistor. Each receiver circuit will operate from a 5 volt power source and will draw about 50 mA. The output from the receiver will be single ended and will be compatible with TTL devices. The receiver will be capable of oeprating from -55°C to 70°C.

5.1 Input Circuit Common Mode Rejection. Signals from dc to 20 mHz with amplitudes up to plus or minus 15 volts peak, line-to-ground shall not cause a receiver maloperation.

5.2 Receiver Sensitivity. The receiver shall respond to a differential input signal with a voltage amplitude of $\pm$ 0.5 volts or greater.

5.3 Receiver Output Voltage Levels. The maximum output low voltage shall not exceed .40 volts and the minimum output high voltage will be greater than 2.4 volts.

5.4 Receiver Strobe Control. It will be the responsibility of the HUD terminal to develop the strobe control signal if any are required.

6.0 SERIAL DATA FORMATS

The AN/ANY-8 will generate the display information for the HUD which will include line segments, circles and numerical characters. The formats compromising these displays will consist of defleciton commands, deflection rates, circle radius, and character definitions. A positive X deflection word will produce a deflection to the right on the HUD and a positive Y defleciton will produce an upper deflection on the

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HUD. All information will be coded into binary two's complement notation for transmission to the HUD system. The radius and seven segment character outputs will always be a positive number. The x,y position for the seven segment character willbe the left edge and will be centered vertically on the digit. A four bit BCD format with bit 12 as the least significant bit will be used to designate the seven segment number.

6.1 Normal Line Segment Format

MSB (bit 16) … LSB (bit 1) ← Computer Bit Position

16	15 …	… 1	
S	X Deflection (15–6)	Message Type (5–1)	Word 1
S	Y Deflection (15–6)	Don't Care (5–1)	Word 2
S	ΔX/Z (15–6)	Don't Care (5–1)	Word 3
S	ΔY/Z (15–6)	Don't Care (5–1)	Word 4
S	Z line length (15–5)	Don't Care (4–1), P	Word 5 plus parity

6.2 Circle Format

MSB

16	15 …	… 1	
S	X Deflection (15–6)	Message Type (5–1)	Word 1
S	Y Deflection (15–6)	Don't Care (5–1)	Word 2
S	Radius (15–5)	Don't Care (4–1)	Word 3
S	Radius (15–5)	Don't Care (4–1)	Word 4
S	Radius (15–5)	Don't Care (4–1), P	Word 5 plus parity

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6.3 **Character Format**

16 (MSB)	15–6	5–1 (LSB)	
S	X Deflection	Message Type	Word 1

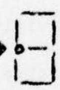
16	15–6	5–1	
S	Y Deflection	Don't Care	Word 2

16–1	
Don't Care	Word 3

16–1	
Don't Care	Word 4

16	15–12	11–1		
S	Number	Don't Care	P	Word 5 plus parity

Reference Point →



7 Segment Character

6.4 **Definition of message type code of word 1** -

5	4	3	2	1 (LSB)	Definition
-	-	0	0	0	ignore information (do not display)
-	-	0	0	1	line segment message
-	-	0	1	0	Character message
-	-	1	0	0	Circle message
0	1	-	-	-	*Start of buffer message
1	0	-	-	-	*End of buffer message

*Start and end of buffer are discrete bits which will be added to the first and last entries of the display buffer in addition to the normal discrete bit which defines the format.

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6.5 Buffer Reset

A dedicated buffer will be provided in the AN/AYK-8 for the storage of the HUD information. Each request signal will cause five words to be read in a sequential manner from the buffer and transmitted. When word five of the last message entered in the buffer has been applied to the data link, the buffer address circuits will be reset to the starting address. On the next request, the first entry in the buffer will be transmitted.

7.0 DATA TRANSFER TIMING

7.1 Normal Operation

To control the information displayed and request signals, a 20 millisecond timer will be provided in the HUD system. The timer will be enabled by the start of buffer code word. In the event all the buffer information has been transferred to the HUD before the 20 millisecond time out period, case 1, figure 5, the request signals will be inhibited after the transmission of the message containing the end of buffer code. The request signals will be reinitiated when the 20 millisecond timer has timed out. The first message transmitted in response to the reinitiated request will contain the start of buffer code which will reset the 20 millisecond timer.

In the event the end of buffer signal occurs after the 20 millisecond time out period, case b, figure 5, the request signals will continue to be transmitted.

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7.2 Initialization

Since the 20 millisecond timing signal is initiated by the buffer start code, special facilities must be provided for the case of power turn-on or until the two systems have become "locked up". At power turn-on, the 20 millisecond timing signal will be generated independently of the buffer start signal, and when it times out a request signal will be generated. The initial request signal shall be mechanized in such a manner that it can remain high for a finite period of time during which the enable signal will be generated by the AN/AYK-8. The request signal will be reset on the first positive going clock signal following the leading edge of the enable signal. The first message transmitted by the AN/AYK-8 in response to the initial request will contain the start of the buffer code.

8.0 MODE CONTROL DISCRETES

The ODU mode switch will be the same as the same as the ASG-26A mode switch and will supply 28 V DC discretes on the ASG-26A wiring to the computer for mode control as follows:

Old Switch Position Marking	New Switch Position Marking
Cage	A-G
A-A	A-A Missiles
Bit 1	A-A Gun 1
Bit 2	A-A Gun 2

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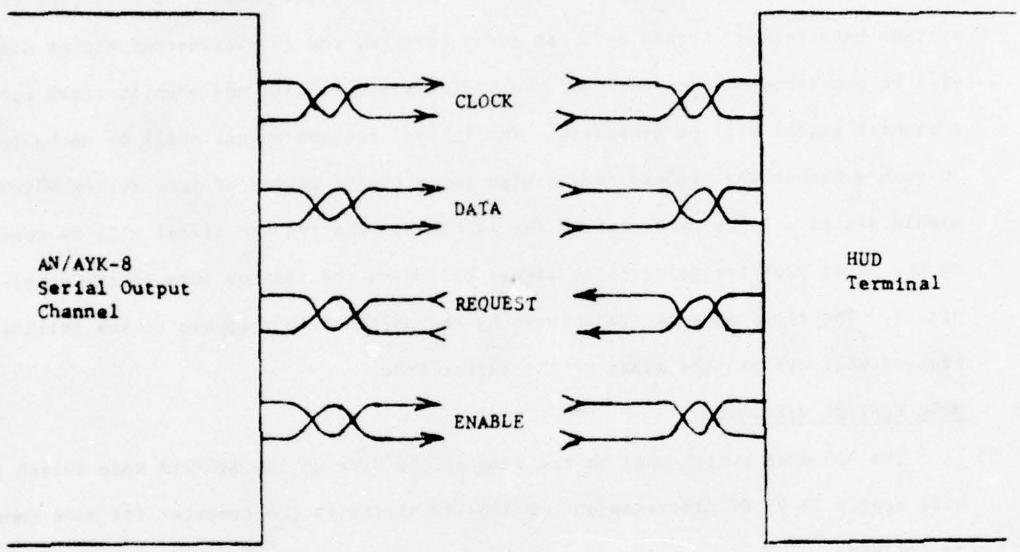

Signal List

Figure 1

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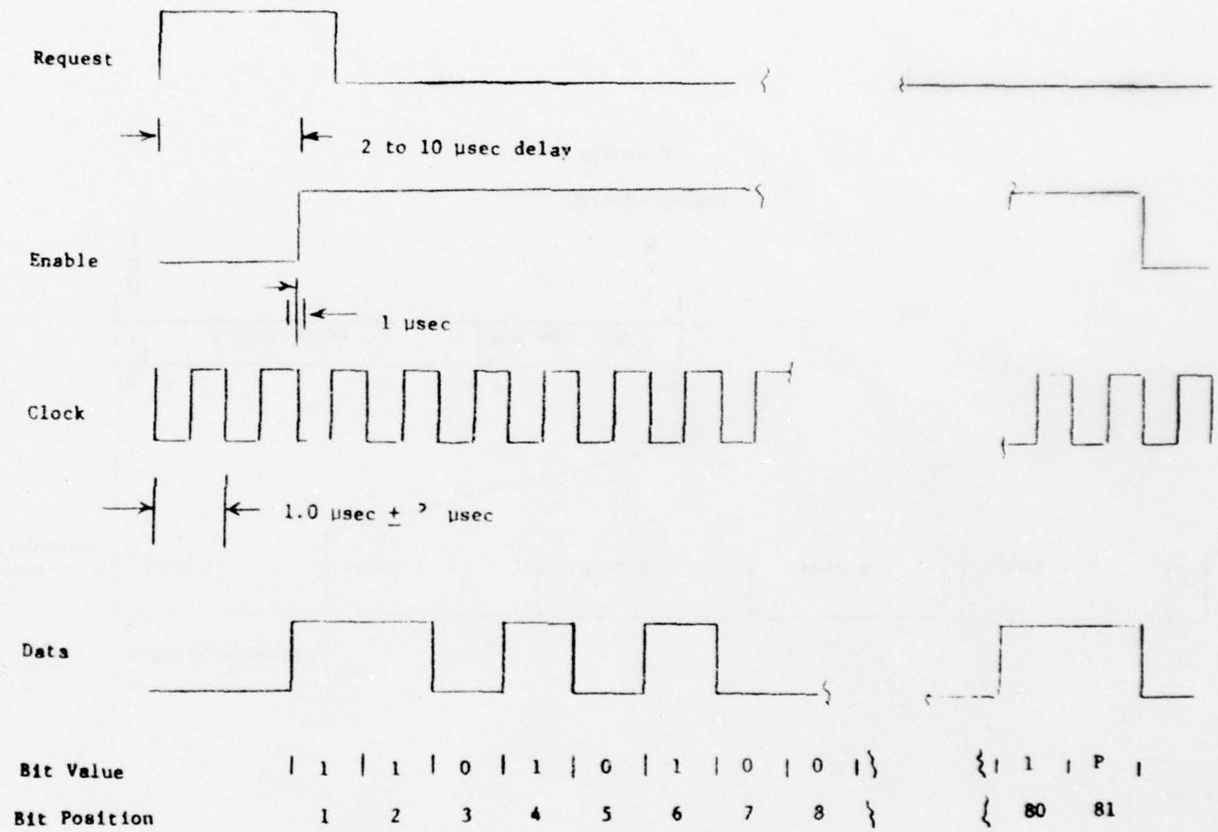

Timing Diagram

Figure 2

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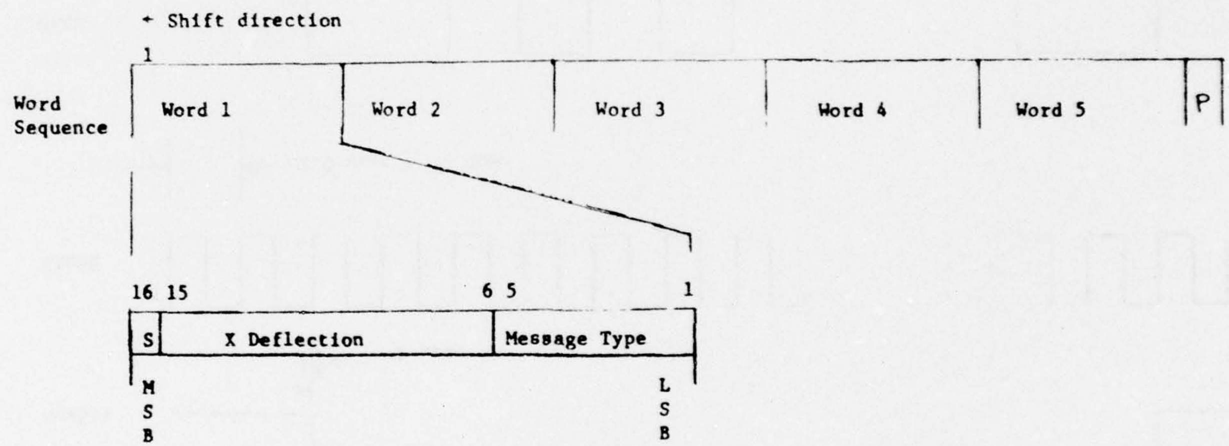

Message Format

Figure 3

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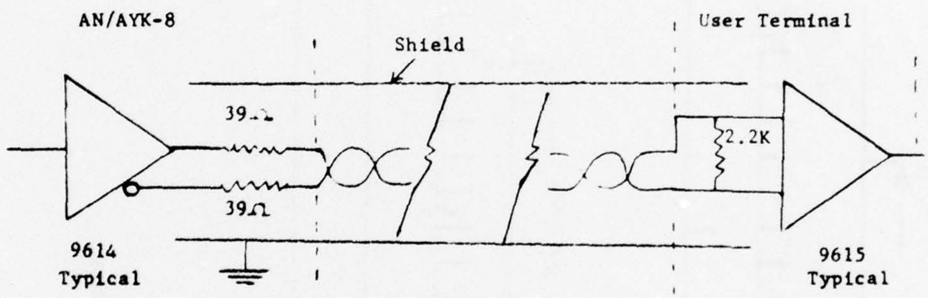

Figure 4. Line Transmitter/
Receiver Interconnections

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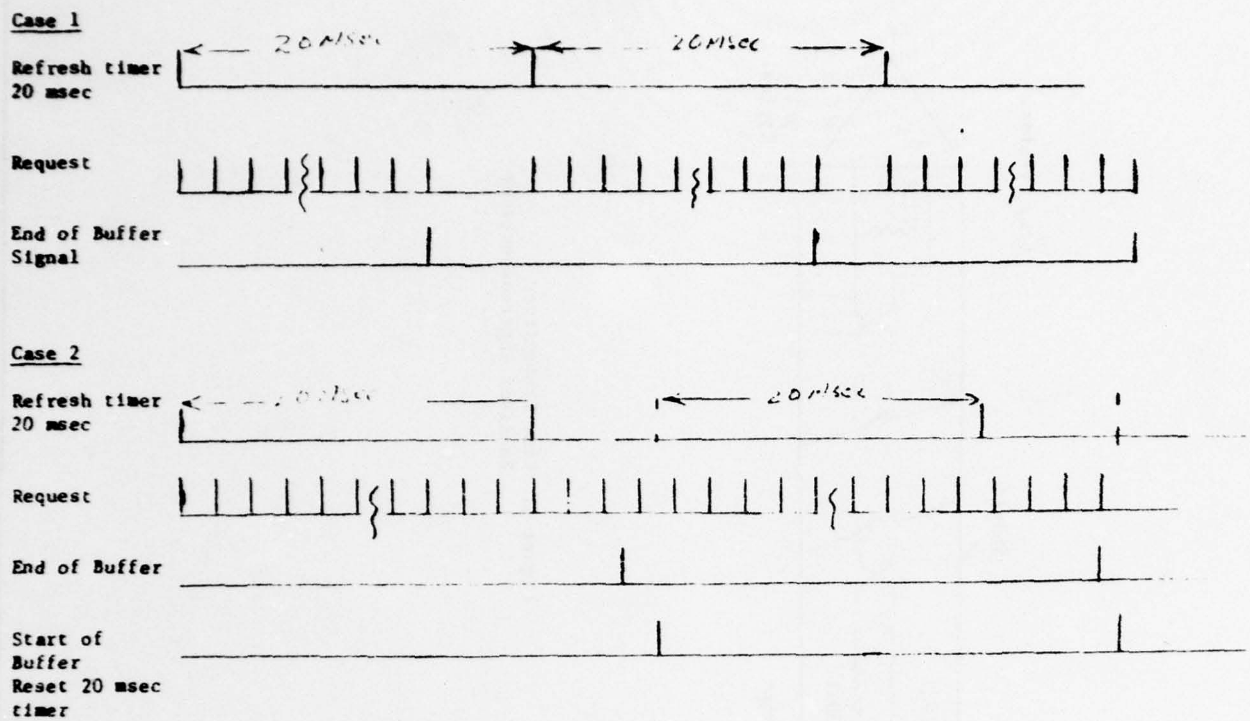

Request Timing

Figure 5

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APPENDIX A2

EXCERPTS FROM MOD II KIT

NOTICE: Appendix A2 contains excerpts from the Class II Modification implemented by Edwards AFB personnel. Quality of copy has suffered greatly due to lack of Air Force original copies at Westinghouse for reproduction.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	MIL–P–27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

CLASS II MODIFICATION - INITIAL INSTALLATION

INITIATION DATE

1. COMPLETE THE FOLLOWING ITEMS PRIOR TO PLACING THE AEROSPACE VEHICLE IN WORK

1. STATEMENT OF REQUIREMENT AND PRELIMINARY VALIDATION

B. PROJECT

(1) TITLE F4E Austere HUD/Gunsight

(2) NUMBER JON 69DFCO

(3) CLASSIFICATION Unclassified

(4) OFFICER	(a) OFFICE SYMBOL	(b) TELEPHONE NUMBER
J.S. Smith, Major	DOTFM	73021

(5) CONTRACTOR	(a) TELEPHONE NUMBER
Westinghouse	74197

(6) PRIORITY	(a) USAF 3-20	(b) AFSC	(c) LOCAL 20

(7) BRIEF DESCRIPTION OF REQUIREMENT, INCLUDING OPERATIONAL DATE REQUIRED

Installation of contractor furnished equipment and wiring for

Austere HUD/Gunsight evaluation.

(8) ANTICIPATED TERMINATION DATE	(9) ANTICIPATED REMOVAL DATE
15 Oct 76	1 Nov 76

(10) REVIEW AND INITIAL APPROVAL BY FLIGHT SAFETY OFFICER

TYPE NAME, GRADE, AND OFFICE SYMBOL		SIGNATURE	DATE
JAMES M. YOUNG, Major, USAF Chief, Programs Branch	DOQP	James M Young	19 Jul 74

(11) REVIEW AND INITIAL APPROVAL BY DIRECTOR OF MATERIEL

TYPE NAME, GRADE, AND OFFICE SYMBOL	SIGNATURE	DATE
not required		

(12) TEST DIRECTOR / AGENCY VALIDATION

TYPE NAME, GRADE, AND OFFICE SYMBOL		SIGNATURE	DATE
JERRY D. BOWLINE, Lt Colonel, USAF Commander, 6512 Test Sqdn	DOT	Jerry D Bowline	19 Jul 1974

2. INITIAL ESTIMATES

a. MODIFICATION NUMBER (7 digits of which the first is an alpha character) M-4-D-0317

b. AEROSPACE VEHICLE EFFECTED (If nonpossessed, cite owning organization authority)

(1) MDS	(2) NUMBER	(3) ORGANIZATION IF NONPOSSESSED
F4E	68-304	

c. DAYS OF DOWN TIME	d. GROUP "B" COMPONENTS COSTS	e. COST OF MANHOURS	f. TOTAL COST
45	$350,000	8000	$358,000

g. IN HOUSE ACCOMPLISHMENT [X] YES [ ] NO (If "NO" state reason and possible contractors)

h. FUND CITATION

74-163

i. CONTRACTED FOR DELIVERY DATES OF GROUP "B" COMPONENTS BY ENGINEERING / PROJECT ELEMENTS

15 Aug. 74

TYPE NAME, GRADE, AND OFFICE SYMBOL	SIGNATURE	DATE
J.S. Smith, Major, DOTFM	J.S. Smith, Major	18 JUL 74

3. INITIAL APPROVAL

TYPE NAME, GRADE, AND OFFICE SYMBOL OF FIELD COMMANDER		SIGNATURE	DATE
JAMES W. WOOD, Colonel, USAF Deputy Commander for Operations	DO	James W Wood	18 JUL 1974

4. ENGINEERING AND ENGINEERING CERTIFICATION

A. AERODYNAMICS / STRESS ANALYSIS

(1) DRAWING (TYPE), REFERENCE	(2) STRESS ANALYSIS [X] YES [ ] NO (If "YES" attach copy)	(3) AERODYNAMIC AND FLIGHT CHARACTERISTICS ANALYSIS (Attach copies)
Form 1659 attached		

(4) WEIGHT AND BALANCE ESTIMATES	(5) WEIGHT CHANGE	(6) CENTER OF GRAVITY
Report attached	+200 lbs.	Report attached

(7) LOAD ANALYSIS

(a) HYDRAULIC (Remarks / Restrictions)	(b) PNEUDRAULIC (Remarks / Restrictions)
N/A	N/A

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CLASS II MODIFICATION - INITIAL INSTALLATION (CONTINUED)

b. ELECTRICAL (Including Circuit Protection)

(1) DRAWING (TREE) REFERENCE: Form 1696

(2) PALLETIZATION (If palletization can not be accomodated, indicate reasons.): N/A

(3) POWER / LOAD ANALYSIS

(a) AC (Remarks / Restrictions)	(b) DC (Remarks / Restrictions)
Uncommitted pwr available 25,241 Volt - Amps. Pwr change for this Mod. Minus 55 volt - Amps	Uncommitted pwr available 85 Amps (2380W.) Pwr req'd for Mod 28 V. 1.2 Amps (33.6W)

c. BILL OF MATERIALS (Attach copy): M. Kuramoto, DOESI — List of Mtls. attached

d. ENGINEERING CERTIFICATE

We (I) have reviewed the engineering design and certify that the modification will not detract from the structural integrity, flight safety, or general airworthiness of the aerospace vehicle. Any anticipated adverse effects or aerodynamic characteristics or the operation of the aerospace vehicle systems have been identified, defined, and evaluated and are operationally acceptable. Anticipated limitations are attached.

TYPE NAME, GRADE, AND OFFICE SYMBOL	SIGNATURE	DATE
DOE		
DOT		
SE		
LGMQ		
LGM		

5. COMMANDER'S REVIEW

a. CLASS II MODIFICATION AFFECTS SAFETY, AERODYNAMICS STABILITY, OR STRUCTURAL INTEGRITY ☐ YES ☐ NO (If "YES" explain)

b. CLASS II MODIFICATION PROPOSAL FORWARDED TO AFSC / LGM OR IF NOT REQUIRED, INDICATE

TYPE NAME, GRADE, AND OFFICE SYMBOL OF COMMANDER	SIGNATURE	DATE
CC		

c. AFSC / LGM REVIEW (1) AFLC / AMA	(2) AFSC / ASD	d. PACKAGE SENT (If required)	e. AFSC / LGM COORDINATION COMPLETED ON (If required)

6. ☐ APPROVED ☐ DISAPPROVED BY

TYPE NAME, GRADE, AND OFFICE SYMBOL OF AFSC COMMANDER	SIGNATURE	DATE

II. COMPLETE THE FOLLOWING ITEMS PRIOR TO RELEASING THE AEROSPACE VEHICLE FOR FLIGHT

7. INSTALLATION

a. MAINTENANCE CONTROL REVIEW

(1) ESTIMATES BY SHOPS (attachments)	(2) SCHEDULING MEETING HELD ON	(3) FABRICATION AND MODIFICATION SCHEDULE TO BEGIN

b. INSTALLATION COMPLETED PER MODIFICATION PACKAGE INSTRUCTIONS

c. OPERATING INSTRUCTIONS (not) ATTACHED.

d. INSPECTION REQUIREMENTS (not) ATTACHED.

e. MAINTENANCE INSTRUCTIONS (not) ATTACHED.

f. SUPPLEMENTARY INSTRUCTIONS (not) ATTACHED.

TYPE NAME, GRADE, AND OFFICE SYMBOL	SIGNATURE	DATE

PAGE 2 OF 3 PAGES

CLASS II MODIFICATION - INITIAL INSTALLATION *(CONTINUED)*

a. CERTIFICATIONS

a. FINAL ENGINEERING CERTIFICATION

I have reviewed the completed modification, find it in conformance with the appropriate drawings / specifications and have made any necessary revisions to the drawings/operating maintenance instructions. Aircrew instructions have been provided to operations.

TYPE NAME, GRADE, AND OFFICE SYMBOL OF ENGINEERING OFFICER	SIGNATURE	DATE

b. FLIGHT / NUCLEAR / LASER SAFETY CERTIFICATION

I have inspected the completed modification and reviewed the operational aspects and note on safety hazards. Any restrictions are noted as attachments.

TYPE NAME, GRADE, AND OFFICE SYMBOL OF FLIGHT SAFETY OFFICER	SIGNATURE	DATE
TYPE NAME, GRADE, AND OFFICE SYMBOL OF NUCLEAR SAFETY OFFICER	SIGNATURE	DATE
TYPE NAME, GRADE, AND OFFICE SYMBOL OF LASER SAFETY OFFICER	SIGNATURE	DATE

c. OPERATIONS CERTIFICATION

I have reviewed the completed modification and reviewed the operational aspects and note on operational limitations. Any additional restrictions/limitations are noted as attachments.

TYPE NAME, GRADE, AND OFFICE SYMBOL OF OPERATIONS OFFICER	SIGNATURE	DATE

d. MAINTENANCE CERTIFICATION

(1) WEIGHT AND BALANCE ACCOMPLISHED *(Itemize group "B" components on chart "A" and annotate on chart).*

(2) "G" FILE UPDATED

(3) MASTER INSPECTION CARDS FILED

(4) MAINTENANCE INSTRUCTIONS, INSPECTION CARDS, ETC., FURNISHED TO AFFECTED WORK CENTERS.

(5) FUNCTIONAL CHECKFLIGHT

(6) INVENTORY ADJUSTED *(DD Form 780, Aircraft Inventory Record)*

(7) AFTO FORM 95 ENTRY COMPLETED, INCLUDING PROJECT NUMBER AND TITLE OR RECORDED IN PCN H871009 *(AFSCM 66-271)*

(8) ENGINEERING TIME / COST

(9) MANHOUR COST

(10) GROUP "B" COMPONENTS COST

(11) EXPENDABLE AND OTHER COSTS

(12) TOTAL COSTS

Modification has been inspected and work performed meets all applicable standards and specifications.

TYPE NAME, GRADE, AND OFFICE SYMBOL OF QUALITY CONTROL OFFICER	SIGNATURE	DATE
TYPE NAME, GRADE, AND OFFICE SYMBOL OF CHIEF OF MAINTENANCE	SIGNATURE	DATE

e. COMMANDERS CERTIFICATION

I certify that I have reviewed all steps in the completion of this Class II modification and have found them completed as prescribed by AFSCR 80-33 and supplements thereto.

TYPE NAME, GRADE, AND OFFICE SYMBOL OF COMMANDER	SIGNATURE	DATE

REMARKS

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F-4E	68-0304	69DFCO	[illegible]	[illegible]

PROJECT ENGINEER PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
1.	Remove door 65R per applicable T.O.				Cook
2.	Remove door 165 per applicable T.O.				Cook
3.	Open door ~~70~~ -174-5L per applicable T.O.				[illegible]
4.	Open radome per applicable T.O.		H. Chund		Cook
5.	Extend AN/APQ 120 radar package per applicable T.O.		H. Chund		Cook
6.	Remove radar Target Intercept Computer CPE91B/APQ120 per applicable T.O. Remain [illegible]		H. Chund		Cook
7.	Remove front cockpit ejection seat bucket per applicable T.O.				Cook
8.	Remove rear cockpit ejection seat bucket per applicable T.O.				Cook
9.	Remove forward Intra Target Data Indicator, IP 1093/APQ 120 E per applicable T.O. [illegible]				Cook
10.	Remove rear Intra Target Data Indicator, IP 1094/APQ 120E per applicable T.O. [illegible]				Cook
11.	Remove Radar Indicator Control Unit, C 8909/APQ 120E per applicable T.O. Remain in custody [illegible]				Cook
12.	Remove Direct View radar scope camera control panel 12464 per applicable T.O. To be re-installed See MDC Class II MOD No. M-4-D-0432		H. [illegible]		Cook

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F-4E	68-0304	69DFCO		

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733(USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
13.	Remove Radar Antenna Control C 7346/APQ 120 per applicable T.O. Re-install, item 112.				
14.	Remove Weapons Delivery Panel (53-81211) per applicable T.O. Remain in custody of [illegible]				
15.	Remove Weapons Release Computer Control Panel C 6480A/ASQ 91 per applicable T.O. Remain in custody of [illegible]				
16.	Remove rear cockpit Navigation Control Panel per applicable T.O.				Cook
17.	Remove Circuit Breaker Panel No. 7 per applicable T.O. Re-install, item 108.				Cook
18.	Remove Communications Control Panel per applicable T.O. Re-install, item 107.	1.0			Cook
19.	Remove forward cockpit Navigation Control Panel per applicable T.O. Re-install, item 110.				Cook
20.	Remove IFF Control Panel per applicable T.O. Re-install, item 105.				Cook
21.	Remove Control Monitor Panel DCU 94A per applicable T.O. Remain in custody of [illegible]				Cook
22.	Remove Compass Control Panel per applicable T.O. Re-install, item 10?.				Cook
23.	Open door 19 per applicable T.O.				Cook
24.	Remove IFF Pulse Decoder 312/ASQ 19 per applicable T.O. Re-install, item 102.				Cook
25.	Remove Ballistic Computer CP 805A/ASQ 91 per applicable T.O. Remain in custody of DOTSH.				Cook

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F-4E	68-0304	69DFCO	[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
26.	Remove Lead Computing Sight Amplifier AM 4224A/ASG 22 per applicable T.O. Remain in custody of [illegible].				[illegible]
27.	Remove Helmet Mounted Sight Ind. Display System per applicable T.O. To be modified and re-installed.				[illegible]
28.	Remove TISEO Video Recorder (Sony) per applicable T.O. See Mod. No. [illegible] To be relocated to instrumentation [illegible].				
29.	Remove TISEO Digital Tracker Unit per applicable T.O. Remain in custody of [illegible].				[illegible]
30.	Remove Upper Equipment Bay (19) Shelf per applicable T.O. Remain in custody of [illegible].				[illegible]
31.	Remove Altitude Encoder P/N 70210 per applicable T.O. See Mod. No. [illegible] To be re-located in [illegible].				[illegible]
32.	Remove Rate Gyro, ASG 26 package per applicable T.O. See Mod. No. [illegible] Remain in custody of [illegible].				[illegible]
33.	Remove existing extraneous wiring applicable to equipment to be permanently removed. NOTE: See MDC Class II Mod Instr.		[illegible]	[illegible]	[illegible]
34.	Pull above mentioned wiring through pressure bulkhead F.S. 203 remove from aircraft.			[illegible]	[illegible]
35.	Dress remaining Upper Equipment Bay (19) cable harness in forward and left side of bay 19 as required.				[illegible]
36.	Install contractor modified Upper Equipment Bay shelf (P/O 9RJ0010) in bay 19 per applicable T.O.			[illegible]	[illegible]
37.	Contractor install AN/AYK 8 Computer Mock-up and form computer harness 9RD 472[illegible] 2nd 9RD 4730 in			[illegible]	[illegible]

AFFTC FORM OCT 73 8

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F-4E	68-0304	69DFCO		

PROJECT ENGINEER PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
	bay 19 (See Note 2.)				
38	Contractor remove AN/AYK 8 Computer Mock-up components.				
39	Remove contractor modified Upper Equipment Bay shelf (P/O 9RJ0010) per applicable T.O. and contractor advisory assistance.				
40	Connect (temporarily) Cable Assembly *9RD4723 to existing LRU 15 connectors 1P1, 1P2, and 1P3.				
*	NOTE: Hereafter referred to as Cable Group 1.				
41	Route Cable Group 1 in-line and parallel to existing LRU 14 pantograph.				
42	Clamp (tie) Cable Group 1 to existing LRU 14 pantograph, breaking away at right extremity.				
43	Route Cable Group 1 through existing lightening hole of F.S. 65.				
44	Clamp Cable Group 1 to F.S. 65 at lightening hole.				
45	Route Cable Group 1 through F.S. 71 at lightening hole.				
46	Clamp Cable Group 1 to FS. 71 at lightening hole.				
47	Remove pressure plug (potting) from existing hole (3) inboard, high on right side of) F.S.77, leaving existing cable bundle intact.				

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F-4E	68-0304	69DFCO	[illegible]	

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO	
J. B. Hellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
48.	Route Cable Group 1 through F.S. 77 at existing hole just vacated.		[illegible]	[illegible]	[illegible]
49.	Route Cable Group 1 downward to area of existing radar cable trunk (right, forward console).		[illegible]	[illegible]	[illegible]
50.	Clamp Cable Group 1 at intervening F.S. as necessary.			[illegible]	[illegible]
51.	Route Cable Group 1 parallel to existing radar cable trunk, forward right console, aft to rear cockpit area.			[illegible]	[illegible]
52.	Route Cable Group 1 parallel to existing radar cable trunk, rear right console, aft to F.S. 203.			[illegible]	[illegible]
53.	Remove existing pressure plug (potting) from hole in F.S. 203 where wires were previously removed (item 33).		[illegible]	[illegible]	[illegible]
54	Route Cable Group 1 through F.S. 203 with remaining wires from bay 19 equipment.			[illegible]	[illegible]
55	Terminate Cable Group 1 with contractor furnished connectors per wiring diagram 9RD4699.		[illegible]	[illegible]	[illegible]
56	Install Scan Converter Cable Ass'ly 9RD4708 parallel to previously installed Cable Group 1 aft into bay 19.		[illegible]	[illegible]	[illegible]
57	Remove potting compound from existing connectors 12P1 (69P 252A) and 12P3 (69P 252C). [illegible] item 13[illegible]	[illegible]	[illegible]		
58	Terminate wires of Cable Ass'ly 9RD4708 at these connectors per wiring diagram 9RD4698.			[illegible]	[illegible]

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F4E	68-0304	69DFCO	[illegible]	[illegible]

PROJECT ENGINEER PLANNER	PHONE NO.	MODIFICATION NO	
J. B. Rellon/S. Slocum	74197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
59	Install contractor furnished stadiometric range control on the inboard throttle grip per Assembly Drawing 9RG2532. (See note 2). (Revised) A [illegible] (D)		[illegible]	[illegible]	[illegible]
60	Install stadiometric Range Cable Assembly 9RD4709 Parallel previous Cable Group 1 installation aft to bay 19.		[illegible]	[illegible]	[illegible]
61	Terminate stadiometric range Cable Assembly 9RD4709 per wiring diagram 9RD4700.		[illegible]	[illegible]	[illegible]
62 (D)	Install 'Shoot Light' on front cockpit ~~windscreen~~ per assembly (Glare Shield) drawing 9RC2533 (See Note 2.).				[illegible]
63 (D)	Install Shoot Light Cable Ass'ly 9RD4710. Dress to ~~righthand wind screen bow~~ ~~left~~ Right Glare Shield to area below front canopy sill, downward ~~to previously installed Cable Group 1~~ [illegible] left Console		[illegible]	[illegible]	[illegible]
64 (D)	Route shoot light Cable Assembly 9RD4710 ~~paralled to previously installed Cable Group 1~~ [illegible] the left Console aft to bay 19.		[illegible]	[illegible]	[illegible]
65	Terminate shoot light Cable Assembly 9RD4710 at the 'Shoot Light' per wiring diagram 9RD4701.		[illegible]		[illegible]
66	Route Scan Converter Cable Ass'ly/ LRUI 9RD4712 paralled to Cable Group 1 forward into radar compartment.		[illegible]	[illegible]	[illegible]
67	Install Scan Converter/LRUI Cable Ass'ly 9RD4712. Leave a service loop at each end, unterminated. [illegible] to Dwk. No. M-4-D-0312-1.		[illegible]	[illegible]	[illegible]
68	Remove left aft cockpit kick panel covering access to Flight Control Amplifier per applicable T.O.			[illegible]	[illegible]

AFFTC FORM OCT 72 8

AD-A042 255 WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 19/5
F-4E FIRE CONTROL SYSTEM SIMULATOR, F-4E AUSTERE/HEADS UP DISPL--ETC(U)
MAY 77 W PATTERSON F33615-74-C-1173
UNCLASSIFIED AFAL-TR-76-190 NL

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AD
A042255

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB CARD NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		27 Aug 74	2 Dec 74

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellen	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISION	QC INSPECTOR
69	Open access door revealing test connectors on front of Flight Control Amplifier. Remove the test connector protective cover per applicable T.O.		[illegible]	[illegible]	
70	Install contractor furnished buffer assembly at Flight Control Amp. test connectors J 905 and J 906 (See NOTE 2) Dwb No. 2539		[illegible]	[illegible]	
71	Connect pigtails per MDC Class II Mod Instructions		[illegible]	[illegible]	
72	Route Computer Control Panel Cable Assembly 9PD4715 from aft right console, parallel to previously installed Cable Group 1 aft into bay 19			Smith	
*	Fit to installed Computer Control Panel Mock-up			Smith	
73	Remove potting compound from the existing Helmet Sight Control Unit connector, 6AJ 3A2A (refer add. item 131)				

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
74	Dress Helmet Sight Cable Assembly 9RD4718 to existing rear cockpit cable runs to area of Cable Group 1		[illegible]		[illegible]
75	Route Helmet Sight Cable Assembly 9RD4718 to previously installed Cable Group 1, aft into bay 19		[illegible]		[illegible]
76	Terminate wires of Helmet Sight Cable Assembly 9RD4718 at Helmet Sight Control Unit connector 64P 3 per Wiring Diagram 9RD4717. Deleted Stow in left wire trough.				
77	Locate splice area AC 5, numbers 72, 73, and 74 from AN/AJB 7 to its accelerometer Revised per item 137		[illegible]	[illegible]	
78	Break the aforementioned splices, cap the AJB 7 ends and splice the wires of Cable Assembly 9RD4722 to the accelerometer ends of splice area AC 5, 72, 73, and 74 per Wiring Diagram 9RD4721. Revised per item 138 & 137		[illegible]	[illegible]	[illegible]

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon	7 4197	M-4-D-031Z	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
79	Route AJB 7 Accelerometer Cable Assembly 9RD4722 parallel to the previously installed Cable Group 1		[illegible]	Smith	Cook
80	Install Power Distributor Cable Assembly 9RD4716 as follows:		[illegible]		[illegible]
81	Route Computer Control Panel segment of Power Distribution Cable Assembly 9RD4716 forward from bay 19 to the previously installed Computer Control Panel connector 5P1 (P/O Cable Assembly 9RD4715)		[illegible]	G. Miller	Cook
82	Terminate additional 5P1 power wires per wiring diagram 9RD4695			Smith	Cook
83	Install contractor furnished 5P2 connector to fit the Computer Control Panel mock-up		[illegible]		Cook
84	Terminate 5P2 wires per wiring diagram 9RD 4695		[illegible]	J. Miller	Cook

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Mellon	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
85	Route the battery segment of the Power Distribution Cable Assembly 9RD 4695(A) ~~9RD4716~~ forward from bay 19 to the aircraft battery.		[illegible]	[illegible]	[illegible]
86	Terminate the battery segment of Power Distribution Cable Assembly 9RD 4695(A) ~~9RD4716~~ at the battery per 9RD 4695		[illegible]	[illegible]	[illegible]
87	Connect the AN/ASQ 91 segment of the Power Distribution Cable Assembly 9RD4716 to AN/ASQ 91 connector 89-P405B		[illegible]	[illegible]	[illegible]
88	Connect the AN/ASG 26 segment of the Power Distribution Cable Assembly 9RD4716 to the AN/ASG 26 Connector 88-P405C			[illegible]	[illegible]
89	Install mode discrete cable 9RD 4714 in bay 19		[illegible]		[illegible]
90	Terminate 9RD 4714 per wiring diagram 9RD4713		[illegible]	[illegible]	[illegible]

AFLC [illegible]

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
91	Install Cable Group 3 (Cable Assembly		[illegible]	[illegible]	[illegible]
	9RD 4724) from Pave Gamma Master				
	Logic Unit, parallel to Cable Group				
	1 into bay 19				
	NOTE: Leave service loop, unter-				
	minated both ends				
92	Group all cables previously routed		[illegible]	[illegible]	[illegible]
	into bay 19 in accordance with their				
	respective terminating connectors.				
	Computer Cable Assembly 9RD4730 is				
	in the forward left area of the				
	upper equipment bay (19)				
93	Make a wire count in confirmation		[illegible]	[illegible]	[illegible]
	that all required wires are				
	accounted for				
94	Terminate all aircraft wiring in the		[illegible]	[illegible]	[illegible]
	contractor supplied aircraft/				
	computer interface connectors in				
	accordance with assigned pins and				
	wire numbers as designated by wiring				
	diagrams for individual Cable				
	Assemblies (Group 1, Group 2, Group 3)				

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellon	7 4197	M-4-D-0317	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
95	Circuit check all Austere HUD		[illegible]	[illegible]	[illegible]
	cable connections				
96	Re-pot all connectors as required		[illegible]		
	per applicable T.O. [illegible]				
97	Inspect all workmanship and				
	installation per applicable T.O.		[illegible]	[illegible]	[illegible]
98	Clamp and/or tie-wrap all Austere		[illegible]	[illegible]	[illegible]
	HUD Cables per applicable T.O. as				
	required, depending upon cables				
	removed or added by the accompanying				
	instrumentation Class II Modifica-				
	tion				
99	Install contractor modified				
	structure assembly 9RJ 0010 in				
	bay 19 per applicable T.O.		[illegible]	[illegible]	[illegible]
100	Contractor install contractor		[illegible]	[illegible]	[illegible]
	supplied peculiar Austere HUD				
	equipment on Structural Assembly				
	9RJ 0010				

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO	
J. B. Hollon	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
101	Install bay 19 equipment peculiar to the accompanying instrumentation Class II Modification			[illegible]	[illegible]
102	Install IFF Pulse Decoder 312/ ASQ 19 per applicable T.O.		[illegible]		
103	Install Compass Control Panel in forward cockpit, right console per applicable T.O.		A McDougal	[illegible]	
104	Install Bomb Monitor Control Panel in forward cockpit, right console per applicable T.O.		[illegible]	[illegible]	
105	Install IFF Control Panel in forward cockpit, right console per the applicable T.O.		[illegible] Sgt	[illegible]	
106	Install Navigation Control Panel in forward cockpit, right console per applicable T.O.		[illegible]	[illegible]	

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER & PLANNER	PHONE NO.	MODIFICATION NO.	
J. B. Hellen	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
107	Install Communications Control Panel		[illegible]	[illegible]	[illegible]
	in forward cockpit, right console				
	per applicable T.O.				
108	Install Circuit Breaker panel No. 7				[illegible]
	in aft cockpit				
109	Install kick-panel left side of aft		[illegible]	[illegible]	[illegible]
	cockpit per applicable T.O.				
110	Install Navigation Control Panel in		[illegible]	[illegible]	[illegible]
	aft cockpit, right console per				
	applicable T.O.				
111	Install contractor furnished			[illegible]	[illegible]
	Computer Control Panel 10C0E24 G07				
	(Mod)				
	NOTE: Installed in space vacated by				
	previously removed Weapons Release Computer Control Panel C 4420A/ASQ 91 and Weapons Del. Panel 53-81211				
112	Install Radar Antenna Control		[illegible]	[illegible]	[illegible]
	C 7346/APQ 120 per applicable T.O.				

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO	JOB ORDER NO	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO	
J. B. Hellon	7 4197	M-4-D-0312	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MAN HOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	Q C INSPECTOR
113	Install Forward Intra Target Data Indicator (FIDI) F33615-73-C-1292, Ser. No. 1 (Mod) per T.O. applicable IP 1093/APQ 120E		[illegible]	[illegible]	[illegible]
114	Install Rear Intra Target Data Indicator F33615-73-A-1292, Ser. No. 001 per T.O. applicable to IP 1094/APQ 120E		[illegible]	[illegible]	[illegible]
115	Install Indicator Control Unit F33615-73-C-1292, Ser. No. 001 per T.O. applicable ICU C8909/APQ 120		[illegible]	[illegible]	[illegible]
116	Install forward ejection seat bucket per applicable T.O.		[illegible]	[illegible]	[illegible]
117	Install rear ejection seat bucket per applicable T.O.		[illegible]	[illegible]	[illegible]
118	Stow AN/APQ 120 radar package per applicable T.O.		[illegible]	[illegible]	[illegible]
119	Prepare aircraft for Radar Operational Check per applicable T.O.		[illegible]	[illegible]	[illegible]

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304			

PROJ. ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO.	
J. D. Hellon	7 4197	M-4-D-031Z	MIL-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
120	Perform all workmanship and safety of flight inspection as in accordance with applicable T.O.				
121	Contractor perform all necessary operational checks of integrated Austere HUD equipment				
122	Close radome per applicable T.O.				
123	Close door 19 per applicable T.O.				
124	Install door 65R per applicable T.O.				
125	Install door 165 per applicable T.O.				
126	Close door 172 per applicable T.O.				
127	INSTALL CLASS II MOD COMPONENT IDENTIFICATION DECALS IAW MIL-P-27733				
	NOTE: PHOTOGRAPHS TO BE TAKEN UPON COMPLETION OF MOD.				

AFPTC [illegible]

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
			[illegible]	[illegible]

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
			MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
128	RADAR - TISEO TRANSFER LOGIC UNIT	0.5	[illegible]		[illegible]
	P/N - 53-07124-1 Removed		F/[illegible]		
129	CONTROL BOX ELECTRONIC	0.5	[illegible]	[illegible]	[illegible]
	3062320 Removed		F/[illegible]		
130	Fabricate "patch cable" with mating connectors MS3-122E-22-55-P/ LWG-M-II-4-031Z (2J/P1) (refer - item 57) MS5-122E-22-55-PW/ (2J/P3)		T. [illegible]	[illegible]	[illegible]
131	Fabricate "patch cable" with mating connector (3) 87-WL0320-44A/ MS27473P18356 (J/P2A) of Helmet (44P344A) Sight Control Unit (refer - item 78)				
132	Install 1 Amp C/B on #2 C/B Panel as per Dwg. II 97742 # (9 RI) 4695		[illegible]	[illegible]	[illegible]
133	Remove 3/8" off of Flange R-H. Control Panel Console Aft. Iub'd Pix		[illegible]	[illegible]	[illegible]

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET					
ACFT TYPE: F4E	ACFT SERIAL NR: 68-0304	PROJ DIRECT NR: 69IIECO	DATE WORK STARTED: 27Aug74	DATE WORK COMPLETED: [illegible]	
PROJ ENGINEER/PLANNER: Maj. Milam J.M. Hollon	PHONE NR: 74197	MODIFICATION NR: M-4-II-0231	MIL-P-27733 (USAF) will apply to all Modification work.		

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
134	Reseal all Pressuri				
	zation Bulkhead				
	Cable Holes Repotted				
	for Cable rerouting		[illegible]	[illegible]	[illegible]
135	Pressurization				
	Leak Check required		[illegible]	[illegible]	[illegible]
	IAW Existing T.O. [illegible]				
136	Fabricate Patch		[illegible]	[illegible]	[illegible]
	Cable for Box 19R5		[illegible]		
	Mating with 19J5				
137	Locate AJB7 Flight		[illegible]	[illegible]	Cook
	Director Bombing Com				
	puter Connector				
	30P326A, pins N, P, Y				
138	Cut and Cap the		[illegible]	[illegible]	Cook
	Computer side of the				
	aforementioned wires.				
139	Splice wires of Cable		[illegible]	[illegible]	Cook
	Assembly 9RD4722 to				
	the accelerometer ends				
	of aforementioned wires				
	per wire list from 9RD4722				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F4E	30304		[illegible]	[illegible]

PROJECT ENGINEER/PLANNER	PHONE NO.	MODIFICATION NO	
		-03E	MIL.-P-27733 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
140 (1)	Install Computer Control Annunciator Panel Lighting transformer in rear cockpit.		[illegible]	[illegible]	[illegible]
141 (1)	Splice transformer into Power Distribution Circuit per drawing no. TEO 4695 (Rev.)		[illegible]	[illegible]	Cook
142 (1)	Install "Over-Temp" light in rear cockpit, per drawing no. 9RB 3555.		[illegible]	[illegible]	Cook
145 (1)	Route "Over-Temp" light wiring(2) to the upper equipment, terminate at [illegible] Connectors 28J6/42 + 28J5/22, per Dwg. No. 9PB3555.		[illegible]	[illegible]	Cook

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AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
-4E	68 0304		27 Aug 74	[illegible]

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
			MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
144	Remove S.S.T. #181		G. [illegible]	[illegible]	[illegible]
	Coaxial Cable in				
	Bay #19 to be Stored				
	in Tisco Room				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AUSTERE HUD
LIST OF MATERIALS

Class II Mod No. M-4-D-031Z

ITEM	QUANTITY	DESCRIPTION *	NOTE
1.	1	AN/AYK 8 Computer, Consisting of: LRU 27 616R487G06 (Mod) LRU 28 616R501G12 (Mod) LRU 29 616R525G17 (Mod)	Contractor Mockup 7 Aug AN/AYK-8 21 Sept
2.	1	AN/AYK 8 Computer Control Panel 1000E24G07 (Mod)	Mockup 7 Aug AN/AYK-8 21 Sept
3.	1	Structure Assembly 9RJ 0010	
4.	1	Stadiometric Range Control Assembly 9RC 2532	Contractor to fabricate bracketry on site
5.	1	Shoot Light Assembly 9RC 2533	
6.	1	Cable Assembly Group 1 9RD 4723	
7.	1	Cable Assembly Group 2 9RD 4707	
8.	1	Cable Assembly Group 3 9RD 4724	
9.	1	Raymond Tape Unit, Consisting of: Electronics Unit 6301-01 Transport 6101-01	Contractor installed and maintained Contractor loaned
10.	1	Power Sequencer, Computer 9RD 4731	Contractor Installed
11.	1	Forward Intra Target Data Indicator (FIDI) P/N F33615-73-C-1292, Ser.No. 001 (Mod)	Texas Instruments supplied before final checkout
12.	1	Optical Display Unit P/N 688207-1	" " "
13.	1	Rear Intra Target Data Indicator P/N F33615-73-C-1292, Ser.No. 001	" " "
14.	1	Indicator Control Unit P/N F33615-73-C-1292 Ser. No. 001	" " "
15.	1	Computer Interconnection Cable	Contractor fabricate on site
16.	1	Input/Output Cable	

* All Class B items plus items 15 and 16 are contractor maintained.

INSPECTION REQUIREMENT and INSTRUCTIONS

1. Inspect all workmanship and installation, for compliance with MIL-P-27733.

2. Inspection Requirements

   a. Preflight:

      (1). Aircraft work area: Rear Cockpit

      (2). Time to preflight: 15 Minutes

      (3). Responsible Section: DOTFM

      (4). Verify System operation, per T.O. 1F-4C-34-1-1CL-1

         (a). AN/APQ 120 Radar, minimum performance standards.

         (b). TISEO, " " "

         (c). AN/AYK 8 Computer " "

         (d). HUD Components " " "

   b. Postflight:

      No requirement

   c. Phase or Hourly:

      (1). Radar System Dehydration for moisture contamination.

      (2). Radar Antenna hydraulics (contamination indicator).

      (3). No Hourly inspection required.

   d. Special Inspection:

      None required

MAINTENANCE INSTRUCTIONS

See Section 4 of attached contractor (Westinghouse) report.

OPERATING INSTRUCTIONS

Austere HUD Class II Modification, F 4E 68-0304. Mod. No. M-4-D-031Z

1. Computer Turn On/Off Sequence.

AN/AYK 8 Computer turn on is accomplished by rotating the FUNCTION switch on the Computer Control Panel (1000E24007) located in the aft right hand console from the OFF to TEST or STANDBY position. Placing the switch in the OFF position removes primary power from the AN/AYK 8 computer and the ODU back-up reticle.

2. Austere HUD Display Equipment.

This modification forms an addition to the existing PAVE GAMMA installation in this aircraft. Existing instructions, plus the above Computer On/Off sequence apply.

DATA LIST

PREPARING ACTIVITY	DESIGN ACTIVITY	CODE IDENT		REV
				A
DATE			SHEET 1 OF 3 SHEETS	

	SPECIFICATION	TYPE, MODEL, SERIES	ITEM NOMENCLATURE
GOVERNMENT			Class II Mod. No. M-4-D-031Z Austere HUD - F 4E 68-0304 All Data included in Appendix D of Modification Package
CONTRACTOR	Westinghouse		
CONTRACT NO. F33615-74-C-1173			

DWG SIZE	CODE IDENT	DOCUMENT IDENTIFICATION NO.	REV	DOCUMENT NOMENCLATURE
D	97942	9RD 4692 (3 of 3)		Austere HUD Modification Installation
"	"	9RD 4693		Austere HUD Modification Functional
"	"	9RD 4694		
"	"	9RD 4695	A	Austere HUD Power Distribution
"	"	9RD 4696		Austere HUD Control/Comp. Interface
"	"	9RD 4697		Austere HUD Instr./Comp. Interface
"	"	9RD 4698	A	Austere HUD Display/Comp. Interface
(W)	AFFTC	M-4-D-031Z-2		Supplement of the above
D	97942	9RD 4699	A	Austere HUD Radar/Comp. Interface
"	"	9RD 4700		Austere HUD Stad. Range Wire Diag.
"	"	9RD 4701	A	Austere HUD Shoot Light Wire Diag.
"	"	9RD 4707		Austere HUD Cable Group 2 (Incl. all thru 9RD 4722)
"	"	9RD 4708		Austere HUD Comp./Display Interface
"	"	9RD 4709		Stadiametric Range Cable Assembly
"	"	9RD 4710		Austere HUD Shoot Light Cable Ass'ly.
"	"	9RD 4712		Austere HUD Scan Conv./LRU 1 Cable
"	"	9RD 4713		Austere HUD Mode Discrete Cable Ass'ly
"	"	9RD 4715		Comp. Control Cable Assembly.
"	"	9RD 4716		Austere HUD Power Dist. Cable Ass'ly.
"	"	9RD 4717	A	Helmet Mounted Sight Wire Diagram
"	"	9RD 4718		Helmet Mounted Sight Cable Ass'ly.
"	"	9RD 4720		Helmet Mounted Sight/LRU 1 Cable Ass'ly.
	(W) AFFTC	M-4-D-031Z-1		Supplement to the above.
D	97942	9RD 4721	A	AJB 7 Accelerometer Wire Diagram
"	"	9 RD 4722		AJB 7 Accelerometer Cable Ass'ly.

AF FORM 1659 OCT 61 REPLACES AF FORM 1302, DEC 57, WHICH IS OBSOLETE.

DATA LIST

PREPARING ACTIVITY	DESIGN ACTIVITY	CODE IDENT		REV
DATE			SHEET 2 OF 3 SHEETS	

	SPECIFICATION	TYPE, MODEL, SERIES	ITEM NOMENCLATURE
GOVERNMENT			Class II Mod. No. M-4-D-031Z Austere HUD - F 4E 68-0304
CONTRACTOR	Westinghouse		All Data included in Appendix D of Modification Package
CONTRACT NO. F33615-74-C-1173			

DWG SIZE	CODE IDENT	DOCUMENT IDENTIFICATION NO.	REV	DOCUMENT NOMENCLATURE
D	97942	9RD 4723		Austere HUD Cable Group 1 Assembly
"	"	9RD 4724		Austere HUD Cable Group 3 Assembly
"	"	9RD 4731		Austere HUD Power Sequencer Ass'ly.
"	"	9RC 2532		Stadiametric Ranging Device Ass'ly.
	(W) AFFTC	9RC 2532	A	Supplementary to the above.
	(W) AFFTC	M-4-D-031-3		Supplementary to the above.
D	97942	9RC 2533		Austere HUD Shoot Light Assembly.
"	"	9RC 2539		Austere HUD/AFCS Interface Wire Diag.
"	"	9RB 3555	A	Computer Over Temperature Light Wire Diagram.
		AFFTC Form 236		Record of Aircraft Equipment Changes
		(W)		Austere HUD Operating Instructions
		(W)		Austere HUD Inspection Requirements
		(W)		Austere HUD Maintenance Instructions

AF FORM 1659 REPLACES AF FORM 1302, DEC 57, WHICH IS OBSOLETE. GPO 924964

DATA LIST

PREPARING ACTIVITY | REVIEW ACTIVITY | CODE IDENT | REV

DATE | SHEET 3 OF 3 SHEETS

	SPECIFICATION	TYPE, MODEL, SERIES
GOVERNMENT		
CONTRACTOR	Westinghouse	

CONTRACT NO. 33615-74-C-1173

ITEM NOMENCLATURE

Class II Mod. No. M-4-D-031Z
Austere HUD - F 4E 68-0304

All Data included in Appendix C
of Modification Package

DWG SIZE	CODE IDENT	DOCUMENT IDENTIFICATION NO.	REV	DOCUMENT NOMENCLATURE
Full Scale		9RJ 0010		Austere HUD Bay 19, Modified Structure
		The following are dwgs. of piece parts of this modification		
B	97942	421R123		Pin, Chassis
"	"	421R 152		Gasket
"	"	9RB 3479		Fitting
"	"	9RB 3480		Fitting
"	"	9RB 3481		Hinge
"	"	9RB 3482		Fitting
"	"	9RB 3483		Gasket
"	"	9RB 3484		Gasket
"	"	9RB 3485		Fitting
"	"	9RB 3487		Filler
"	"	9RB 3488		Stiffener
"	"	9RB 3489		Stiffener
"	"	9RB 3490		Stiffener
"	"	9RB 3504		Fitting
"	"	9RB 3505		Doubler
"	"	9RB 3506		Angle
"	"	9RB 3507		Stiffener
"	"	9RB 3508		Spacer
"	"	9RB 3509		Fitting
"	"	9RB 3510		Spacer
"	"	9RB 3511		Angle
"	"	9RB 3512		Doubler Angle
"	"	9RB 3513		Pin
"	"	9RB 3514		Guide
"	"	9RB 3515		Track
"	"	9RB 3516		Fitting
"	"	9RD 4683		Plenum Cover
"	"	9RD 4684		Plenum Skin
"	"	9RD 4685		Left Side Skin
"	"	9RD 4689		Chassis Assembly
"	"	9RD 4688		Pallet Assembly

AF FORM 1659 REPLACES AF FORM 1399, DEC 57, WHICH IS OBSOLETE. GPO 924004

RECORD OF AIRCRAFT EQUIPMENT CHANGES

AIRCRAFT MODEL	SERIAL NUMBER	DATE	PAGE OF PAGES
[illegible]	68-0304	5 August/74	

INSTRUCTIONS Submit when fixed operating equipment is added, removed from, or relocated in the aircraft, and modification or structural change is made. Items entered on this form will be entered in the Weight and Balance Handbook by personnel of the Weights Section.

CHANGE ACTION CATEGORY: CHART A BASIC EQUIPMENT — INSTALLED — REMOVED — RELOCATED

MODIFICATION: INITIAL INSTALLATION — COMPLETE REMOVAL — MODIFICATION CHANGE

GROUP B COMPONENT: TEMPORARY — PERMANENT — REMOVED — GROUP A PARTS — INSTALLED — REMOVED

COMPARTMENT	EQUIPMENT NOMENCLATURE / LOCATION		AUTHORITY FOR ACTION	CODE A - Added R - Removed	WEIGHT Pounds	MOMENT ARM (Inches) HORIZONTAL	LATERAL	VERTICAL
Door 19	AN/AYK 8 Computer, LRU 27	F.S. 2[illegible]		A	40			
"	Helmet Sight IDS Power Supply	F.S. 2[illegible]		R	15			
"	AN/AYK 8 Computer, LRU 28	F.S. 234		A	35			
"	Ballistic Computer, CP 805A/ASQ 91	F.S. 234		R	40			
"	AN/AYK 8 Computer, LRU 29	F.S. 242		A	33			
"	LCOSS Amplifier, 4224A/ASG 22	F. S. 242		R	3[illegible]			
"	Raymond Tape Handler	F.S. 234		A	8.1			
"	~~Synchro Followers~~	~~F. S 234~~		~~A~~	~~6~~			
"	Helmet Sight IDS Power Supply (re-packaged)	F.S. 234		A	5			
"	~~SONY Video Tape Recorder~~	~~F.S. 234~~		~~R~~	~~18~~			
"	Power Sequencer	F.S. 2[illegible]		A	[illegible]			
Rear Cockpit	Weapons Delivery Panel, C6430A/ASQ 91	F.S. [illegible]		R	3			
	Bomb Control Monitor, DCU 94A	F.S. [illegible]		R	.2			
	AN/AYK 8 Computer Control Panel	F.S. [illegible]		A	7.5			
	Intra-Target Data Indicator, IP1094/APQ 120E	F.S. [illegible]		R	29.[illegible]			
	Intra-Target Data Indicator, F33615-73-C-[illegible]	F.S. [illegible]		A	2[illegible].2			
	Indicator Control, C8909/APQ 120E	F.S. [illegible]		R	[illegible]			
	Indicator Control, F33615-73-C-1292	F.S. [illegible]		A	[illegible]			
Forward Cockpit	Intra-Target Data Indicator, IP[illegible]/APQ [illegible]	F.S. [illegible]		R	[illegible]			
	Intra-Target Data Indicator, F3361[illegible]-73-C-[illegible]	F.S. [illegible]		A	[illegible]			
	Shoot Light (Instrument Glare Shield)	F.S. [illegible]		A	.2			
	Stadiometric Range Device (Fwd. Throttle)	F.S. [illegible]		A	[illegible]			
Radar Comp't	Target Intercept Computer, CP[illegible]B/APQ 12[illegible]	F.S. [illegible]		R	43.7			

SIGNATURE OF PERSON ACCOMPLISHING CHANGE	ORGANIZATIONAL SYMBOL	DUTY PHONE NUMBER	DISPOSITION OF EQUIPMENT: MOD SECTION — BASE SUPPLY — TEST SUPPLY

CERTIFICATION OF CHANGE

SIGNATURE OF AIRCRAFT CREW CHIEF	DATE	SIGNATURE OF MOD DOCK CHIEF	DATE	SIGNATURE OF WEIGHT & BALANCE EXPERT	DATE

[illegible] Arms required for Crew Escape M[illegible]

AFFTC FORM FEB 73 236 PREVIOUS EDITIONS ARE OBSOLETE

CLASS II MODIFICATION CHANGE ORDER (CO)

F 4E	66-0304	M-4-D-0312 - A

MATERIAL REQUIREMENTS	YES	NO
MUST BE ...		X
...		X
...		X
FURNISHED		X

...	YES	NO
...		X
... ANALYSIS		X
HYDRAULIC ANALYSIS		X
OPERATING INSTRUCTIONS		X
MAINTENANCE INSTRUCTIONS		X
STRESS ANALYSIS		X

DRAWINGS EFFECTED: None

DATA LIST ATTACHED: X

MODIFICATION ENGINEER	OFFICE SYMBOL	DUTY PHONE NUMBER	DATE SUBMITTED
J. B. Hellon/ S. L. Slocum	DOESI	7 2031	10 September 74

DESCRIPTION OF MODIFICATION: Removal of CORDS wiring per Hill AFB authorization dated 16 Sep 74 (copy attached).

1. Remove existing CORDS wire bundle #53-790005-150 from aircraft forward fuselage (FF) area.
   a. Locate and identify that portion (to be retained) of said bundle that is terminated by connector 66-418.
   b. Separate 66-418 cable from wire bundle 53-790005-150 for retention in Bay 19. (Bushing 53-A347, F.S. 208)
   c. Locate splice area 22 in rear cockpit - disconnect all FF-150 wires pertinent to the CORDS portion of wire bundle 53-790005-150. (retain all wires pertinent to Altitude Encoder, connector 66-418)
   d. Cut and cap any additional FF-150 wires in the splice 22 area, pull terminal ends through F.S. 208 at bushing

APPROVAL

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
PROJECT MANAGER: D. W. Milam, Major	Daniel W Milam	11 SEP 74
SYSTEM SAFETY REPRESENTATIVE: K. W. Brotnov, L/Col.	Daniel W Milam (FOR)	11 SEP 74

MAINTENANCE

SHOP ESTIMATES (Hours) (Days)	DAYS DOWN TIME

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
QUALITY CONTROL REVIEW		
DRAWINGS FORWARDED		
INSTRUMENTATION INSTR RCVD		
...		
...		
... COMPLETED		

COST INFORMATION

...	...	MAINT MANHRS	... MANHOURS	TOTAL
$	$	$	$	$

MAINTENANCE CERTIFICATION (Records Updated)

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
...		
...		
...		
...		
WEIGHT AND BALANCE		
QUALITY CONTROL		

FINAL CERTIFICATION

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
PROJECT ...		
...		
SAFETY		
OPERATIONS		

AFFTC FORM 9 OCT 72

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304			

PROJECT ENGINEER PLANNER	PHONE NO	MODIFICATION NO	
J. B. Hellon/ S. L. Slocum	7 4197	M-4-D-031 A	MIL-P-27735 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	Q C INSPECTOR
1.	Locate forward fuselage (FF) wire bundle 53-790005-150 (this bundle is terminated in the upper equip't bay by connectors 61 P475 A, C, & D, 66 P418 and 61 P476 C, D, & F, and extends forward through F. S. 205 at bushing 53-A347).		[illegible]	[illegible]	
2.	Cut all tie-wrap and strip the black braid from the terminal ends to splice area (AC-22) in the aft cockpit.		[illegible]	[illegible]	
3.	Separate the (40) wires terminated by 66 P418 and tie them back. (these wires are listed in the attached wire tabulation, and are to be retained)		[illegible]	[illegible]	
4.	Locate splice area (FF-28) in the upper equipment bay. (the bulk of the CORDS wires to be removed may be cut or disconnected at this point.		[illegible]	[illegible]	
5.	Cut or disconnect at (FF-28) the (48) wires of bundle 53-790005-150 as listed in the attached wire tabulation.		[illegible]		
6.	Pull the aforementioned (48) wires through bushing 53-A347 into the aft cockpit and cut again in the area of splice (AC-22).		[illegible]		
7.	Locate splice areas (AC-7) and (AC-20) in the aft cockpit. Cut or disconnect (2) single wires at these points. Wire no.'s indicated on the attached wire tabulation.		[illegible]	[illegible]	

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NO.	JOB ORDER NO.	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	63-0304			

PROJECT ENGINEER PLANNER	PHONE NO	MODIFICATION NO	
J. B. Hellon/S. L. Slocum	7 -4197	M-4-D-031A	MIL-P-27735 (USAF) will apply to all Modification work.

ITEM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
8.	Locate splice area (AC-22) in the aft cockpit. Cut or disconnect(3) wires at or near this point as indicated by the attached wire tabulation.		TMBlelen	D. Miller	
9.	The remaining (34) wires to be removed go far forward, consequently may be cut at or near splice area (AC-22). These wire no.'s are listed on the attached wire tabulation.		TMBlelon	D. Miller	
10.	Terminal connector 61 P 476C, D, and F will now lift out of the upper equipment bay with terminal connector 61 P475C. The portion of the bundle terminated by 61 P475 A & B are now removable from the upper equipment bay.		TMBlelen	D. Miller	
11.	Cap and dress all severed ends and restore boots to any opened splice areas.				

AFFTC FORM OCT 71 3

DATA LIST

PREPARING ACTIVITY	DESIGN ACTIVITY	CODE IDENT		REV
			SHEET 1 OF 1 SHEETS	

	SPECIFICATION	TYPE, MODEL, SERIES	ITEM NOMENCLATURE
GOVERNMENT			
CONTRACTOR	Westinghouse		
CONTRACT NO	F33615-74-C-1173		

NO. ITEM	CODE IDENT	DOCUMENT IDENTIFICATION NO.	REV	DOCUMENT NOMENCLATURE
		M-4-D-031Z (A)-1	A	F 4E Forward Fuselage Wire Bundle 53-790005-150 (FF-150)
				Wire Tabulation Forward Fuselage Wire Bundle 53-790005-150 (FF-150)

FORM 1659 DEC 61 REPLACES AF FORM 1303, DEC 57, WHICH IS OBSOLETE. GPO 834886

Class II Modification No. M-4-D-0312 - F 4E AF Ser. No. 68-0304

Wire Tabulation of F 4E Forward Fuselage Wire Bundle 53-790005-150

1. That portion terminated by connector 66 P418 in the upper equipment bay and by splice area (AC-22). To be retained.

Wire No.

F 213B	F 224C	F 235G	SX 806A
F 214B	F 225C	F 237C	SX 807A
F 215C	F 226C	F 238C	SX 808A
F 216C	F 228E	F 239C	SX 809A
F 217C	F 230C	F 240D	SX 810A
F 218C	F 231C	F 240D	SX 811A
F 219C	F 232C	F 240F	SX 812A
F 221C	F 233C	SX 705L	SX 813A
F 222B	F 234A to Grd. 452		SX 814A
F 223C	F 234B " " "		SX 815A
			SX 816A
			L188GG to (AC-7)

2. That portion terminated by connector 61 P475A & D in the upper equipment bay and by splice area (FF-28) in the upper equipment bay. To be removed at (FF-28)

Wire No.

SAREFG	TG 2573A	TG 2614A	TG 2603A
SA 981G	TG 2574A	TG 2613A	TG 2602A
SA 985G	TG 2575A	TG 2612A	TG 2601A
TG 1223F	TG 2594A	TG 2611A	TG 2600A
TG 1357F	TG 2647A	TG 2610A	TG 2599A
TG 2465B	TG 2646A	TG 2609A	TG 2598A
TG 2522A	TG 2619A	TG 2608A	TG 2590A (2)
TG 2564A	TG 2618A	TG 2607A	TG 2589A
TG 2568A	TG 2617A	TG 2606A	TG 1306A
TG 2569A	TG 2616A	TG 2605A	TG 1303C
TG 2570A	TG 2615A	TG 2604A	TG 1292D
TG 1120C	TG 1075C	TG 1066C	TG IREFD

3. That portion terminated by connector 61 P475A and splice area (AC-20). To be removed at (AC-20).

Wire No. SQ 22696C

4. That portion terminated by connector 61 P475A and splice area (AC-7). To be removed at (AC-7(.

Wire No. TG 2522A (2) wires

5. That portion terminated by connector 61 P475D, C and splice area (AC-22). To be removed at splice (AC-22).

Wire No.

TG 2567A
TG 2566A
TG 2562A
TG 2563A
TG 2REFA

6. That portion terminated by 61 P475C and 61 P476C, D, and F may be lifted out of the upper equipment bay.

Wire Tabulation of F 4E Forward Fuselage Wire Bundle 53-790005-150 (FF-150)

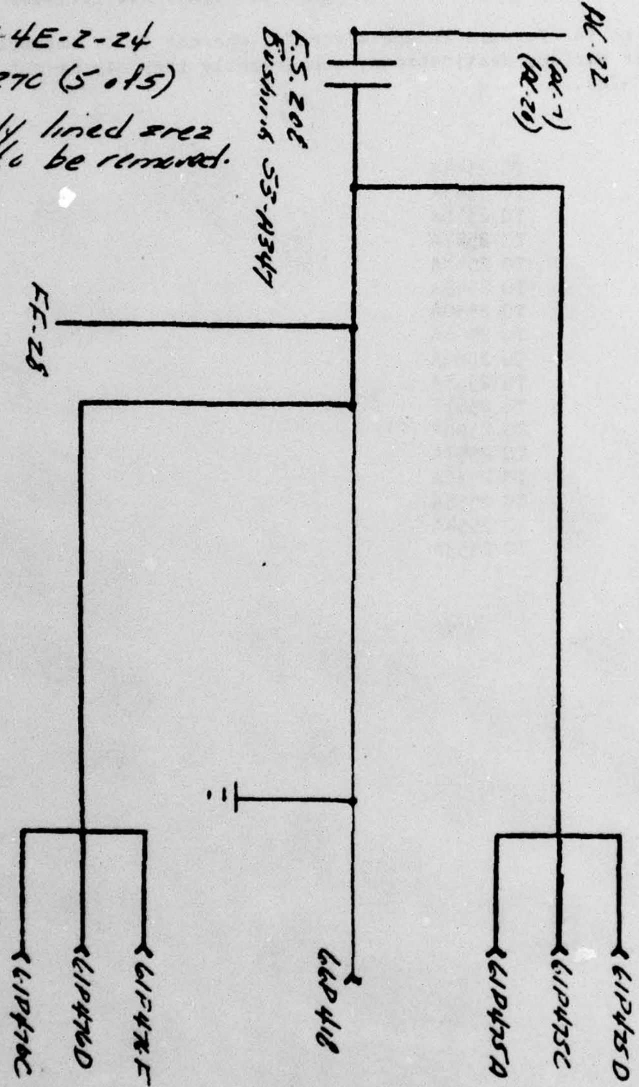
7. The remaining (35) wires go far forward in the aircraft, whereas it is impractical to trace them out to their various destinations, consequently they may be cut in the area of splice (AC-22).

Wire No.

TG 2526A (2)	TG 2544A
TG 2527A	TG 2545A
TG 2528A	TG 2546A
TG 2529A	TG 2547A
TG 2530A	TG 2548A
TG 2531A (2)	TG 2549A
TG 2532A	TG 2550A
TG 2533A	TG 2551A
TG 2534A	TG 2560A
TG 2535A	TG 2565A
TG 2536A	TG 2565E
TG 2537A	TG 2558A (2)
TG 2538A	TG 2557A
TG 2539A	TG 2556A
TG 2540A	TG 2555A
TG 2541A	TG 2554A
TG 2542A	TG 2553A
TG 2543A	

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED

Ref. T.O. 1F-4E-2-24
fig. 4-27C (5 of 5)
Note: Heavily lined area only to be removed.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
.XX ±
.XXX ± ±

DR S. Slocum
CHK
ENG S. Slocum
A.F. AUTHENTICATION
A.F. RELEASE

U.S. AIR FORCE

TITLE
F 4E Forward Fuselage Wire Bundle
53-790005-150 (FF-150)

SIZE A | A.F. CODE IDENT NO. | DRAWING NO. M-4-D-0317 (A)-1
SCALE | SHEET 1 OF 1

FORM 1452 PREVIOUS EDITION WILL BE USED — ENGINEERING DRAWING LAYOUT A VERTICAL

LGM LG R/F

LGMQ

LGMC

F4 [illegible]

[illegible] 65 37

RECEIVED
10 SEP 1974
QC

RCTUZEL [illegible] RUWRHIF [illegible] 77 2[illegible] 203 [illegible]
ZNR UUUUU
R [illegible]1420Z SEP 74
FM [illegible] HILL AFB UTAH [illegible]
TO [illegible] AF [illegible]
INFO [illegible]
[illegible]
1
[illegible]
SUBJ REMOVAL OF [illegible] FOR F-4[illegible]
THIS MSG IS TO CONFIRM [illegible]
[illegible] SEP 74
CONCERNING [illegible]
COMPLETELY IF POSSIBLE [illegible] IS [illegible]
[illegible]
DOCUMENTATION [illegible]
[illegible]
65377

[illegible]

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APPENDIX A3

F-4E AUSTERE HUD PROGRAM
FLIGHT SAFETY ANALYSIS REPORT

Contract No. F33615-74-C-1173

Amendment No. 1
Paragraph 5.4

August 2, 1974

WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER
Baltimore, Maryland 21203

1.0 Purpose for Tapping into Flight Control Amplifiers

The various tasks of the Austere HUD Program include not only the evaluations of the HUD and HUD symbology, but evaluation of two gun solutions, Tracer and ALCOSS, as well. These gun solutions require as inputs measurements of aircraft angular rate and acceleration in space. It is desirable to make as much use of existing onboard sensors as possible, so far as is practical. The rate gyros and lateral accelerometer present in the Flight Control System would appear to partially fulfil the requirements for aircraft rate measurements (normal and longitudinal acceleration would have to be provided elsewhere). If it can satisfactorily be shown that tapping into the Flight Control System to extract these signals does not endanger flight safety and in addition that these measurements are suitable, in terms of range and accuracy, then the practicality and suitability of using these signals is demonstrated. This report examines the flight safety aspects while signal suitability will be determined during flight tests.

2.0 Proposed Interface Design

The ground rules for interfacing with the Flight Control System are that no modifications are to be made in the Flight Control System equipment. Electrical connections to the Flight Control System are to be made through test connectors on the Flight Control Amplifier, which are normally not used during flight. Loading effects caused by making such connections must be shown not to cause excessive degradation of signals during normal operation or during any reasonable failure mode.

The initial plan was to use buffer amplifiers to isolate the Austere HUD circuits from the Flight Control System circuits and to reduce the probability of a short on the buffer input side by mounting the buffers so as to form a rigid part of the connecting plug. Later information, however, indicates that this is not feasible. There is not space enough to permit mounting plugs, with potted buffering circuits attached, to the Flight Control Amplifier without modification of the Flight Control Amplifier housing.

The present plan is to mount voltage dividers on the amplifier output signals and bring out the divider point and ground reference as shown in Figure 1. The dividers will be set at a value of 0.1 with the large divider resistor value 100 Kohm. Load on each circuit is: 100 Kohm in the AN/AYK-8 computer I/O input amplifier and 500 Kohm in the pod signal conditioning circuits. For these loads the smaller divider resistor value is 12.82 Kohm. This plan would require fewer and smaller parts to be mounted at the connector, thus reducing the probability of mechanical interference with the amplifier cover. A preliminary mechanical layout of two connectors is shown in Figures 9 and 8.

3.0 Loading Effects on the Flight Control Amplifier Circuits

Various kinds of loading effects which might occur on the circuits of the Flight Control Amplifier when the proposed tie-in is made are discussed in this section.

A. Resistive Load

The resistive load of each divider circuit is designed to be 110 Kohm. Up to the present time it has not been possible to determine the output resistance of the rate gyros and lateral accelerometer.

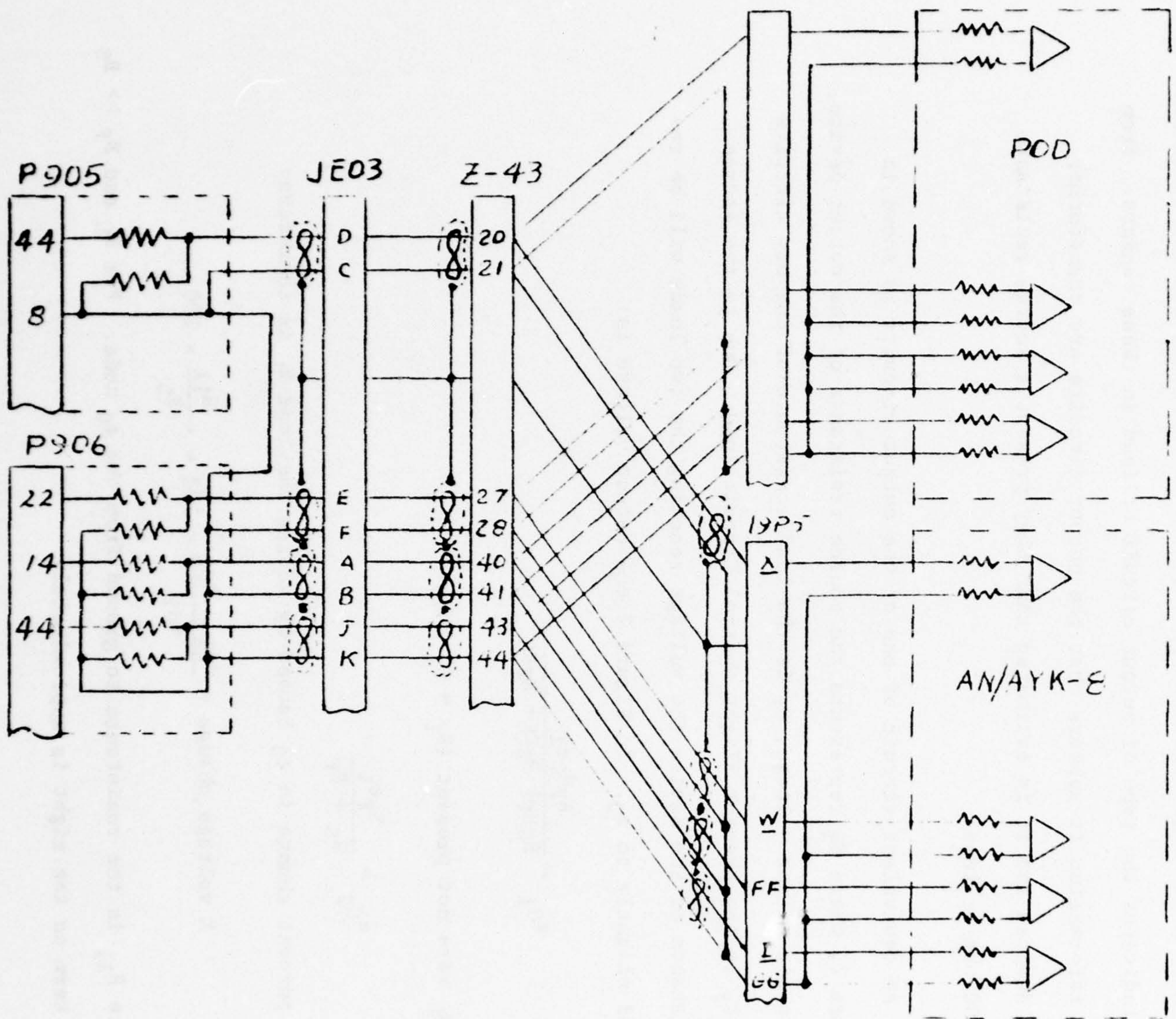


Figure 1. Proposed Flight Controller Interface

information has not been available. However, the maintenance instructions for "Automatic Flight Control System," T.O. 1F-4E-2-16, has been available and indicates the type of output circuit utlized in these sensors. From this information it appears that the output circuits are transformer type devices and it is estimated that they present a source resistance of 200 ohm or less.

An equivalent circuit of one of the output circuits is shown in Figure 2, where R_S represents the source resistance of the output device, e_i is its output voltage, R_L is the load resistance of the new circuits and R_F is the present Flight Control Circuit load. Due to the source resistance of the device the voltage reaching the two loads will be reduced slightly to e_0. In Figure 2 the output voltage is:

$$e_{0_1} = \frac{R_F R_L e_i}{R_S R_F + R_S R_L + R_F R_L}$$

If R_L were not present ($R_L = \infty$) then:

$$e_{0_2} = \frac{R_F e_i}{R_S + R_F}$$

The percent change in e_0 caused by adding the load R_L is therefore:

$$\%\ \text{voltage change} = \frac{e_{01} - e_{02}}{e_{02}} \times 100 = -\frac{R_{11}}{R_L} \times 100$$

where R_{11} is the resistance to ground from the e_0 node. For R_L and $R_F >> R_S$ the term on the right is approximately

$$\approx -\frac{R_S}{R_L} \times 100$$

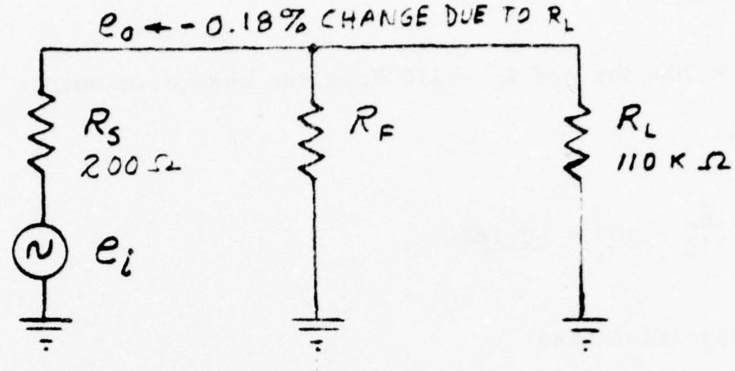


Figure 2.

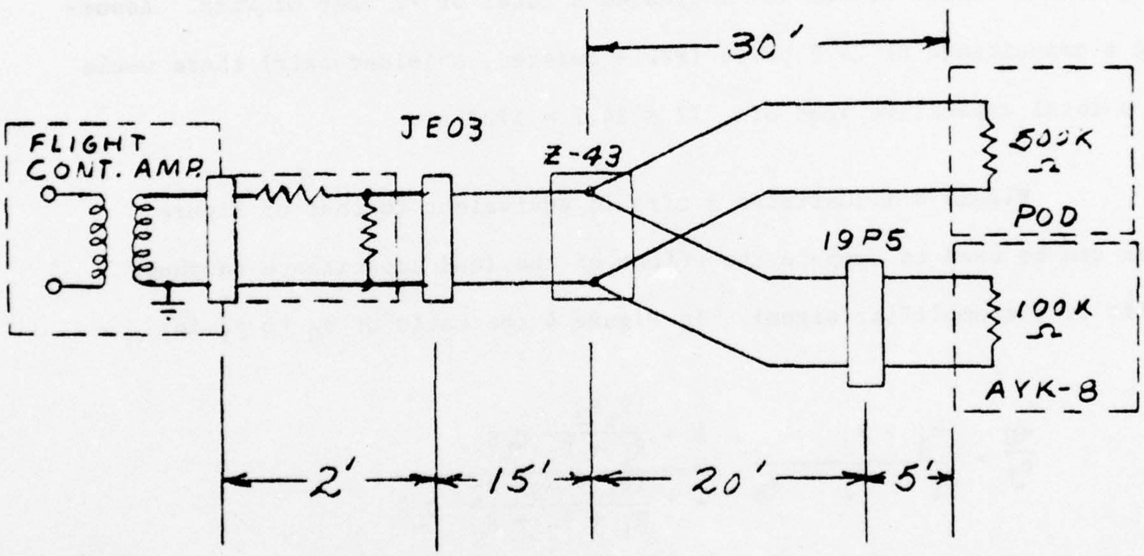


Figure 3.

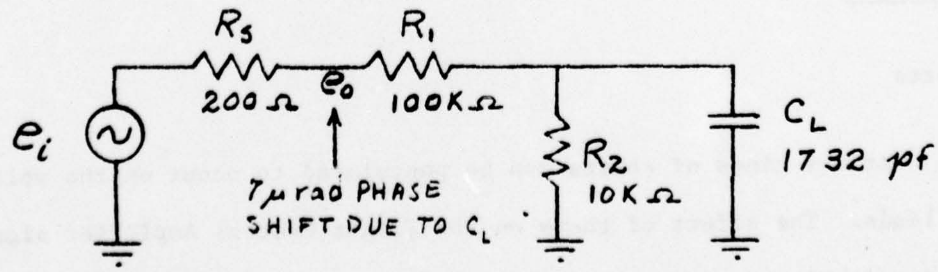


Figure 4.

Assuming R_S = 200 ohm and R_L = 110 Kohm the change in output voltage by adding R_L is:

$$-\frac{.2}{110} \times 100 = \underline{-0.18\%}$$

B. Capacitive Load

Figure 3 illustrates a typical circuit with approximate line lengths indicated. There is indicated a total of 72 feet of wire. Assuming a capacitance of 24.2 pf/ft (#22 - twisted, shielded pair) there would be a total capacitive load of: 72 × 24.2 = 1732 pf.

Figure 4 illustrates a circuit equivalent to that of Figure 3 that can be used to compute the effect of the load capacitance on phase shift of the amplifier signal. In Figure 4 the ratio of e_0 to e_i is:

$$\frac{e_0}{e_i} = \frac{R_1 + R_2}{R_1 + R_2 + R_S} \quad \frac{1 + \frac{R_1 R_2}{R_1 + R_2} C_L S}{1 + \frac{(R_1 + R_S) R_2}{R_1 + R_2 + R_S} C_L S}$$

Using the circuit values given in Figure 4 the phase shift at 400 Hz is <u>7 microradians</u>.

4.0 Shorts

Various kinds of shorts can be postulated to occur on the voltage divider leads. The effect of these on the Flight Control Amplifier signals is considered below.

A. Voltage Divider Short

A diagram of this short is shown in Figure 5. Using the previously derived equation:

$$\% \text{ voltage change} = \frac{R_S}{R_L} \times 100$$

and a new value of R_L of 100 Kohm, R_1 in Figure 5, the % voltage change due to load is:

$$\% \text{ voltage change} = \frac{200}{100\ K} \times 100$$

$$= \underline{0.2\%}$$

a change of: $0.18 - 0.20 = \underline{-.02\%}$, insignificant.

B. Amplifier Short

For this short it is assumed that an I/O scaling amplifier fails in such a way that a supply voltage appears at the amplifier summing point and is thereby introduced into the Flight Control Amplifier circuits. This is an unlikely short, but one that can be conceived of happening and is therefore considered. A diagram of this short is shown in Figure 6. The equation for v is:

$$v = \frac{V\, R_2 R_S}{R_2(R_1 + R_S) + R_3(R_1 + R_S + R_2)}$$

For the values given in Figure 6 and assuming that the supply voltage V is 15 VDC the value of v is <u>3 millivolts DC</u>.

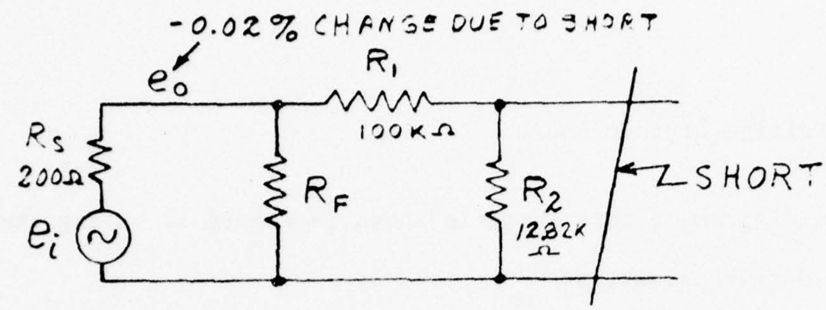


Figure 5.

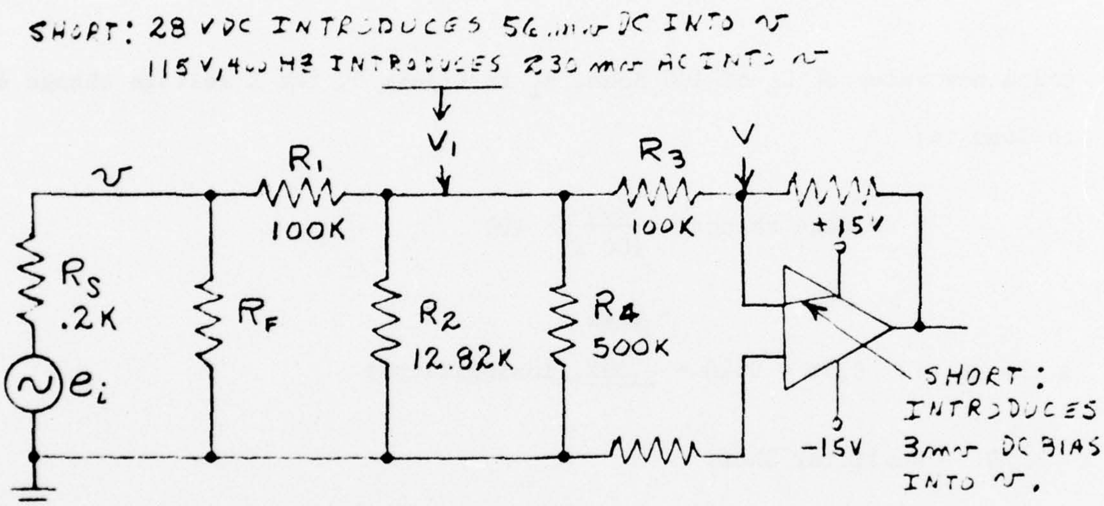


Figure 6.

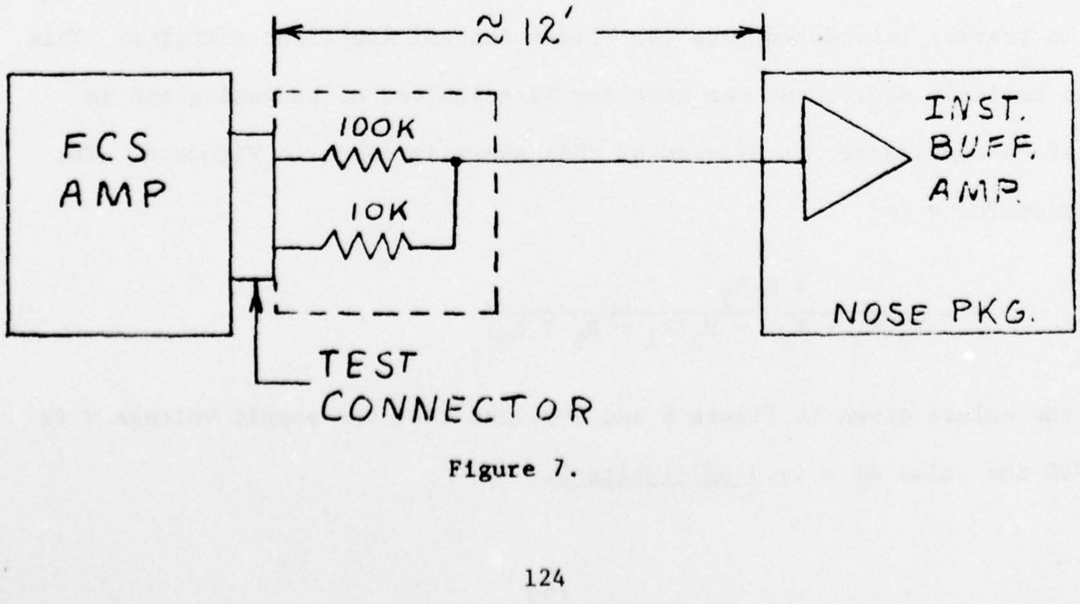


Figure 7.

C. Voltage Short

There are cables in the aircraft carrying 28 VDC and 115 V, 400 Hz power. Assuming one of these can somehow come in contact with the signal wire from one of the voltage dividers and short to it a signal could then be introduced into this circuit in the Flight Control Amplifier. This is shown in Figure 6 as the voltage V_1. It is an extremely unlikely occurrence but is considered for the purpose of determining its effect. From Figure 6 the equation for v is:

$$v = \frac{R_S}{R_1 + R_S} V_1$$

$$= .002\ V_1$$

For: $V_1 = 28$ VDC

<u>$v = 56$ millivolts DC</u>, may only cause slight non-linearity.

For: $V_1 = 115$ V, 400 Hz

<u>$v = 230$ millivolts rms, 400 Hz</u>, worst case.

For the case where 28 VDC shorts to the divider and 56 mv DC is introduced into the Control Amplifier circuits the effect may not be serious but depends on the configuration of the circuits. If the circuits are AC coupled the DC current would be blocked and have no effect other than to change the operating point on the sensor pickoff magnetization curve slightly. If the circuits are direct coupled then the amplifier DC operating point would also be shifted and the large valued AC signals may be clipped on one peak. Higher gain amplifiers may tend to saturate.

In the case of the 115 V, 400 Hz short the effect would be to introduce a signal bias of 230 millivolts. This corresponds to a bias of <u>.82 deg/sec</u> on the angular rate signals. The tolerance of the rate gyros is

$\pm10\%$ and at maximum output (50 deg/sec) 0.82 deg/sec corresponds to 1.64% of maximum.

5.0 Precedent for Use of Voltage Dividers

Voltage divider networks have been used for tapping into the Flight Control Amplifier on a previous Air Force project, i.e., "RIVET GYRO". The purpose was to monitor and provide instrumented data on the rate gyro output signals of the Flight Control System of an RF-4C. The work was done at Wright-Patterson AFB under: Project Director, Capt. Jim Marsh; Wright-Patterson AFB Instrumentation: Charles Thomas; test conducted by: Flight Test Wing Wright-Patterson AFB; approved by: Wright-Patterson AFB Flight Test Director. Plans are now underway by the Air Force at Wright-Patterson AFB to repeat these tests. The technique used is illustrated in Figure 7. Westinghouse is using this Air Force design as the safety buffer isolation.

6.0 Single Point Flight Control Failure Analysis

A report has been generated by MDC summarizing the analysis of effects from a single point failure in the flight control system. The MDC report concludes that critical or catastrophic conditions do not exist from failures in the flight control system amplifiers, from which place the signals would be tapped off for the F4E Austere HUD test.

7.0 Conclusions

The analysis has indicated that no serious effect can be expected on the Flight Control Amplifier gyro and accelerometer output signals when voltage dividers as described in the report are connected to these signal circuits. Shorts to ground or in the scaling amplifier will cause

no problem. Shorts to 28 VDC and 115 V, 400 Hz are least likely to occur but should not cause damage. Their effect is more pronounced than the other types of shorts, but do not appear to be extremely serious.

Flight Control Amplifiers have been on order but as yet have not been received. They will be used for testing the buffer circuits to verify that no adverse effects result from application of the divider circuits or during the various failure modes.

8.0 Subsequent Safety of Flight Meeting

Major Vic Trouy arranged a meeting at Wright-Patterson AFB between Flight Control experts from the AFFDL, F4 SPO representatives, F4E HUD Project people and Westinghouse. Attendance for the meeting of August 2, 1974 at Building 22 was as follows:

Mr. Dave Carlton, AFFDL Project Engineer, Rivet Gyro

Major Vic Trouy, F4E HUD Program

Capt. John Koger, F4E HUD Program Manager

Lt. Norm Beck, F4E HUD Program

Mr. George Williams, Westinghouse Engineering

Mr. John Gregory, Westinghouse F4E HUD Program Manager

The conclusions of the meeting are summarized as follows:

1. The single point flight control failure analysis performed by MDC for the F4 SPO shows: no major problems during malfunction of any of the flight control gyros or accelerometer amplifiers. When such malfunction occurs, normal T.O. procedures indicated in 1F4-1 manual are to be used. This

same procedure is to be used should the tap off of the flight control signals, used in the F4E Austere HUD Program, cause any malfunction to the flight control system. A copy of the single point analysis report by MDC is found in Appendix G.

2. A precedent was already set for use of aircraft flight control signals, by the Air Force Rivet Gyro Project, for instrumentation purposes. Westinghouse is using the same isolation circuit for safety purposes.

3. The Westinghouse analysis showed no major effect will be experienced on the flight control amplifiers from usage of the signals for weapons and instrumentation purposes.

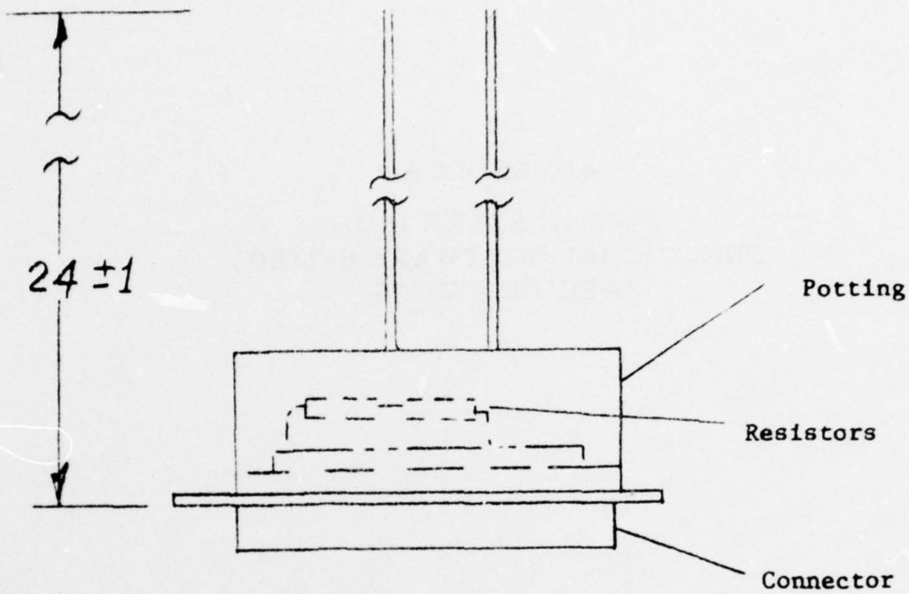


Figure 8. Preliminary Connector Layout - P905

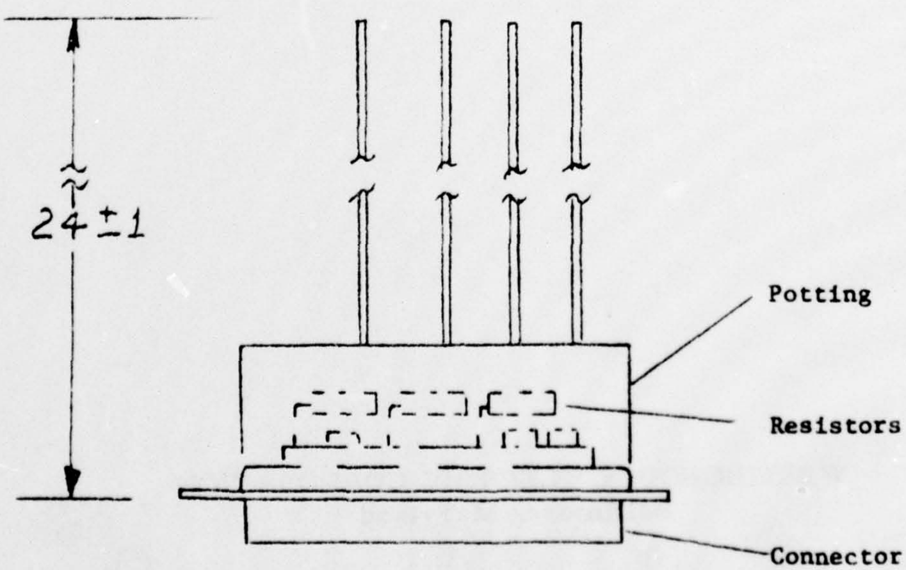


Figure 9. Preliminary Connector Layout - P906

APPENDIX A4

F-4E AUSTERE HUD
FUNCTIONAL SOFTWARE SYMBOL
SPECIFICATIONS

January 10, 1975

WESTINGHOUSE ELECTRIC CORPORATION
Baltimore, Maryland

I. Introduction

This report contains a description of the symbols to be displayed on the Austere Hud during the various modes of operation. The Hud is capable of displaying lines and circles of various sizes and locations in the field of view. It can also display characters at specified locations. Each line, circle or character can be considered a symbol element. A symbol displayed on the Hud is, in general, composed of a group of these symbol elements, i.e., lines, circles and/or characters. An example is the velocity vector symbol which is composed of three line segments and a circle. In this case each element bears a fixed relationship to the other elements so as to form an identifiable symbol and in addition the group moves about the field of view in unison so as to indicate the location of the velocity vector.

The HUD unit draws each symbol element in succession, in the sequence in which information is provided to it by the computer. The information required by the HUD unit to draw any symbol element is contained in a five word digital message. The information contained in the five words for each symbol type is given below.

Word #	1	2	3	4	5
Word Symbol	X_o	Y_0	$\Delta X/Z$	$\Delta Y/Z$	Z
Line Segment	X_o, MT	Y_0	$\cos\theta$	$\sin\theta$	Z
Circle	X_o, MT	Y_0	Radius	Radius	Radius
Numeral	X_o, MT	Y_0	-	-	N

In the above listing X_o and Y_0 are the coordinates of the starting point for drawing a line, location of the center of a circle to be drawn or location of a character to be drawn; θ is the angle that a line to be drawn makes with the positive X axis; Z is the line length; N is the value of a number to be displayed and MT is a code to signify the type of symbol to be displayed.

The computer makes any computations necessary to generate the message words, prepares the message in the proper format and stores it in a frame table. The frame table contains a listing of all of the symbol element message words corresponding to the set of symbols that are to be displayed in a given system mode. The computer transmits the messages in this table, in a serial fashion, to the HUD when data requests are received from the HUD.

Timing

The basic write time for painting a line is 1.1 μs per mr. Time required for painting any diameter circle is 345 μs. Time required for painting a character is 33 μs.

There is a 207 μs settling time required prior to painting any symbol element; line, circle or character. There is an initial delay to transfer the first message into the display buffers of 81 μs.

The various symbol element groups which are utilized in the various modal displays are illustrated in the glossary of Section II.

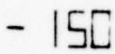
Illustration of the displays available in the various system modes are shown in Section III.

Symbol specifications, arranged in the required five-word format, are given in Section IV together with the necessary equations for computing symbol parameters, as necessary.

XI. GLOSSARY OF SYMBOL ELEMENT GROUPS

The symbol element groups utilized in the various mode displays are briefly described below:

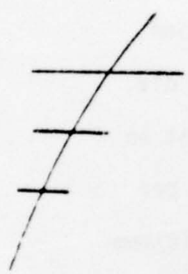
Gun Cross - Indicates the direction of the ADL.



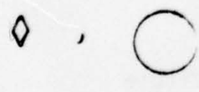
Range Rate - Time rate of change of radar range in knots.

Rounds Remaining - Indicates the number of rounds of gun ammunition remaining in hundreds of rounds.

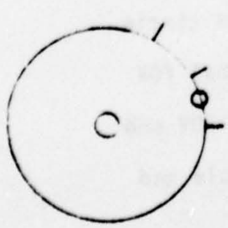
Velocity Vector - Indicates the direction of the true air speed vector or the ground speed vector, as determined by mode selection.



Tracer Line and Range Bars - Indicates bullet trajectory as seen through the HUD. Included with the tracer line are stadiametric range bars located at points on the line corresponding to 1000, 2000 and 3000 feet of range and sized to correspond to the selected wing span at these ranges.

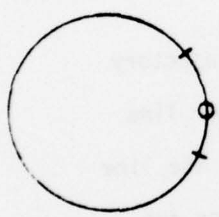


Tracer Line Range Markers - When radar mode is selected the diamond is placed on the tracer line at the point corresponding to radar range. When manual mode is selected a circle, sized to correspond to the selected wing span and the manual range input, is placed on the tracer line at the point corresponding to the manual range input.

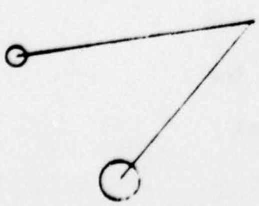


ALCOSS Aiming Reticle - This symbol consists of a 6 mil dia. piper circle and a large concentric reticle circle which also serves as a range scale. The location of the

center of these circles indicates the computed aim point to be placed on the target. When radar mode is selected the large reticle circle has a 50 mr diameter. When manual mode is selected the reticle circle is stadiametrically sized to correspond to the selected wing span at the manual range input. Fixed 4 mil range bars are located at 1, 2 and 3 o'clock positions on the reticle circle corresponding to 1000, 2000 and 3000 feet of range. A 4 mil dia. circle centered on the reticle indicates either radar range or the manual range input.

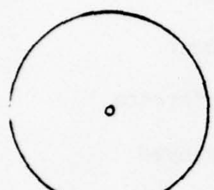


Missile Mode Reticle - This is a 50 mil dia. reticle circle centered on the gun cross. It serves as a range scale where zero range is at the 12 o'clock position. Radar range is indicated on this scale by a 4 mil dia. circle centered on the reticle circle and placed at an angle corresponding to a scale factor of 1 degree per 100 feet of range, measured clockwise. Missile minimum and maximum allowable launch range are also displayed as 4 mil range bars with angular position based on this scale factor. Maximum display range is 27K ft.

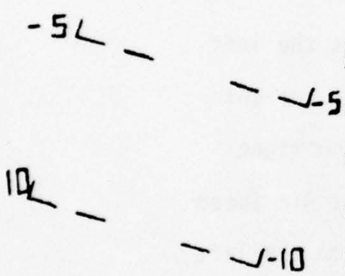


Target Designator - This symbol is a 10 mil dia. circle indicating the direction of the line-of-sight to the target. If the LOS is in the total FOV but outside the instantaneous FOV, a line joins the center of the circle and the Gun Cross. If the LOS is outside the total FOV the line terminates at the boundary of the total FOV and a 5 mil dia. circle replaces the 10 mil dia. circle and is placed at the line termination.

<u>Steering Bug</u> - Indicates the direction of the computed steering course, achieved by flying the plane to place the Velocity Vector symbol over the Steering Bug.

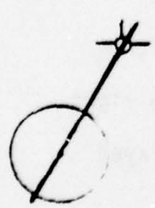


<u>Sight Reticle</u> - Consists of 50 mil reticle and concentric 2 mil piper. Center of circles indicates aim point to be placed over target in Air-to-Ground Modes. When Manual Mode is selected the reticle is set to a preselected depression angle below the Fuselage Reference Line. When Automatic Mode is selected the reticle indicates the Continuously Computed Impact Point (CCIP).



<u>Pitch Lines</u> - Lines drawn parallel to the horizon line and separated by 5 degree increments. Positive pitch lines have wings or tabs directed toward horizon (down), negative lines have a break and wings directed toward horizon (up). Pitch angle of each line, except horizon line is indicated by numerals at each end of the line.

<u>Reference Dive Angle Indicator</u> - Indicates selected dive angle in Air-to-Ground Manual Mode. Not roll sensitive. Selected dive angle achieved when Velocity Vector symbol and Reference Dive Angle Indicator are aligned.



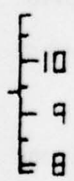
<u>Bomb Fall Line</u> - Line joining Velocity Vector symbol and Sight Reticle in Air-To-Ground Automatic Mode to indicate the track of a stick of bombs.

<u>Reference Air Speed Scale</u> - A verticle scale at the left in the HUD FOV, when displayed, indicating deviation of True Air Speed from a preset value. The three markers to the left of the vertical line are: the Reference Air Speed indexed at the center, and the upper and lower scale limits

(± 50 knots). The right hand marker indicates deviation from the Reference Air Speed.

Reference Altitude Scale - A vertical scale at the right of the HUD FOV, when displayed, indicating deviation of altitude from a preselected value. Upper and lower scale limit markers (± 1000 ft.) and an altitude reference index, representing the selected altitude, are displayed on the right side of the scale. The current altitude deviation from the reference is indicated by the marker on the left side of the scale.

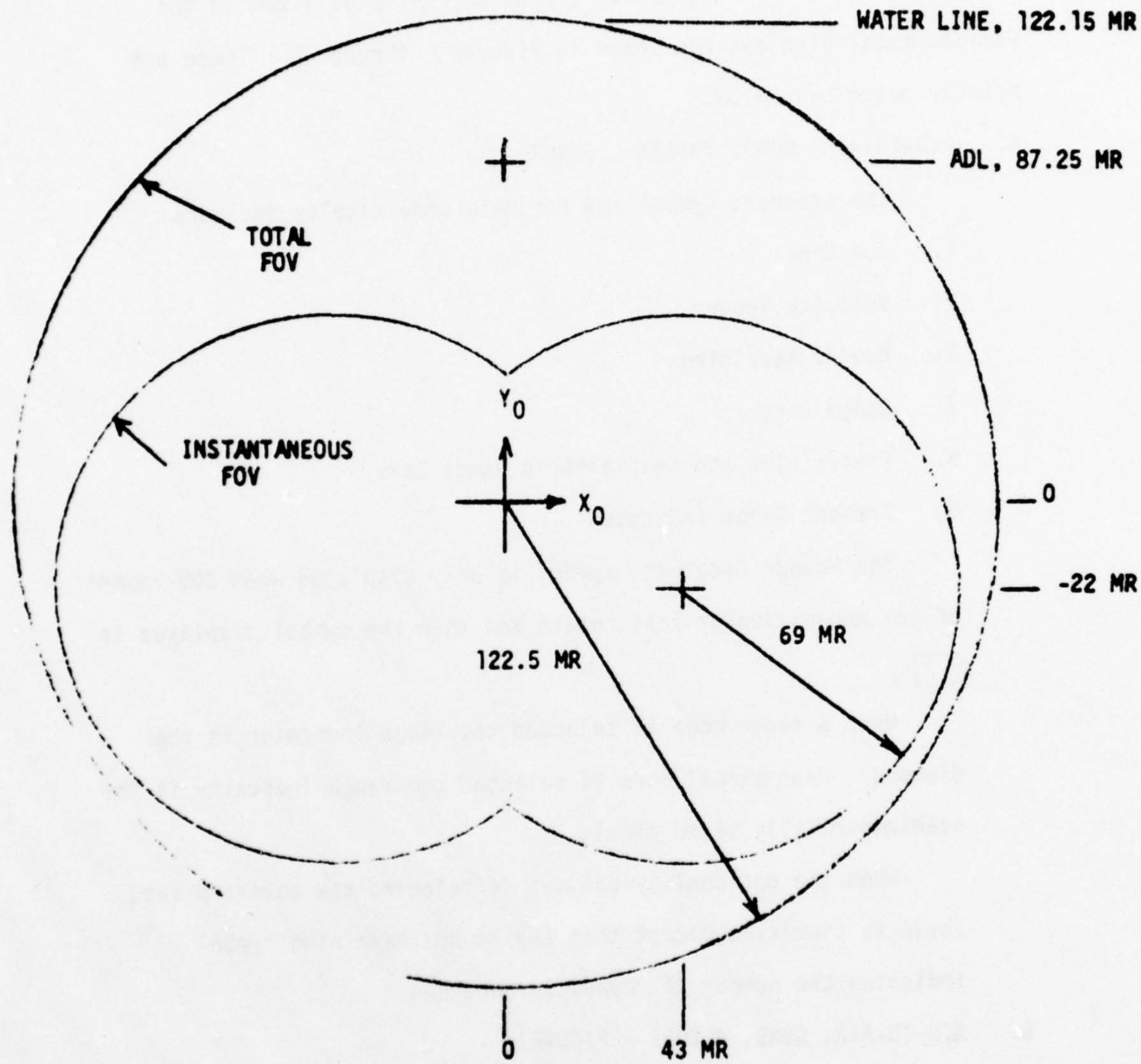
Moveable Air Speed Scale - A vertical scale at the left of the HUD FOV, when displayed, indicating the current aircraft Air Speed. A fixed index drawn at the right center of the vertical scale indicates current Air Speed on a set of moveable scale graduations drawn on the left of the vertical line. A span of 300 knots is displayed on the moveable scale.



Moveable Altitude Scale - A vertical scale at the right of the HUD FOV, when displayed, indicating the current aircraft altitude. A fixed index drawn at the left center of the vertical scale indicates current altitude on a set of moveable scale graduations drawn on the right of the vertical line. A span of 3000 feet is displayed on the moveable scale.

HUD Fields of View

The HUD total field of view and instantaneous field of view and their relationship to aircraft reference line is illustrated in Figure 1.



HUD FIELDS OF VIEW

FIGURE 1

III. MODAL DISPLAYS

Illustrations of the symbol groups currently utilized in the various modal displays are shown in Figures 2 through 7. These are briefly described below:

A. AIR-TO-AIR, GUNS, TRACER - FIGURE 2

The standard symbol set for this mode display includes:

1. Gun Cross
2. Velocity Vector
3. Rounds Remaining
4. Range Rate
5. Tracer Line and Stadiametric Range Bars
6. Present Range Indicator

The Rounds Remaining symbol is only displayed when 200 rounds of gun ammunition or less remain and then the symbol displayed is $\boxed{2}$.

When a radar mode is selected the range indicator is the diamond. When manual mode is selected the range indicator is the stadiametrically sized circle.

When the optional symbol set is selected the standard set, above, is displayed except that the Rounds Remaining symbol indicates the number of rounds in hundreds.

B. AIR-TO-AIR, GUNS, ALCOSS - FIGURE 3

The standard symbol set for this mode display includes:

1. Gun Cross
2. Velocity Vector
3. Rounds Remaining

4. Range Rate

5. ALCOSS Aiming Reticle

The Rounds Remaining symbol is only displayed when 200 rounds of gun ammunition or less remain and then the symbol displayed is $\boxed{2}$.

When the optional symbol set is selected the standard set, above, is displayed except that the Rounds Remaining symbol indicates the number of rounds in hundreds.

C. AIR-TO-AIR, MISSILE - FIGURE 4

The standard symbol set for this mode includes:

1. Gun Cross
2. Velocity Vector
3. Steering Bug
4. Missile Mode Reticle
5. Range Rate

In addition a cockpit SHOOT light is energized when missile launch conditions are satisfied.

When the optional symbol set is selected the Target Designator and Moveable Altitude Scale are displayed in addition to the standard set.

D. AIR-TO-GROUND, MANUAL - FIGURE 5

The standard symbol set for this mode includes:

1. Gun Cross
2. Velocity Vector
3. Sight Reticle
4. Reference Dive Angle Indicator
5. Reference Air Speed Scale
6. Reference Altitude Scale

E. AIR-TO-GROUND, CCIP - FIGURE 6

The standard symbol set for this mode includes:

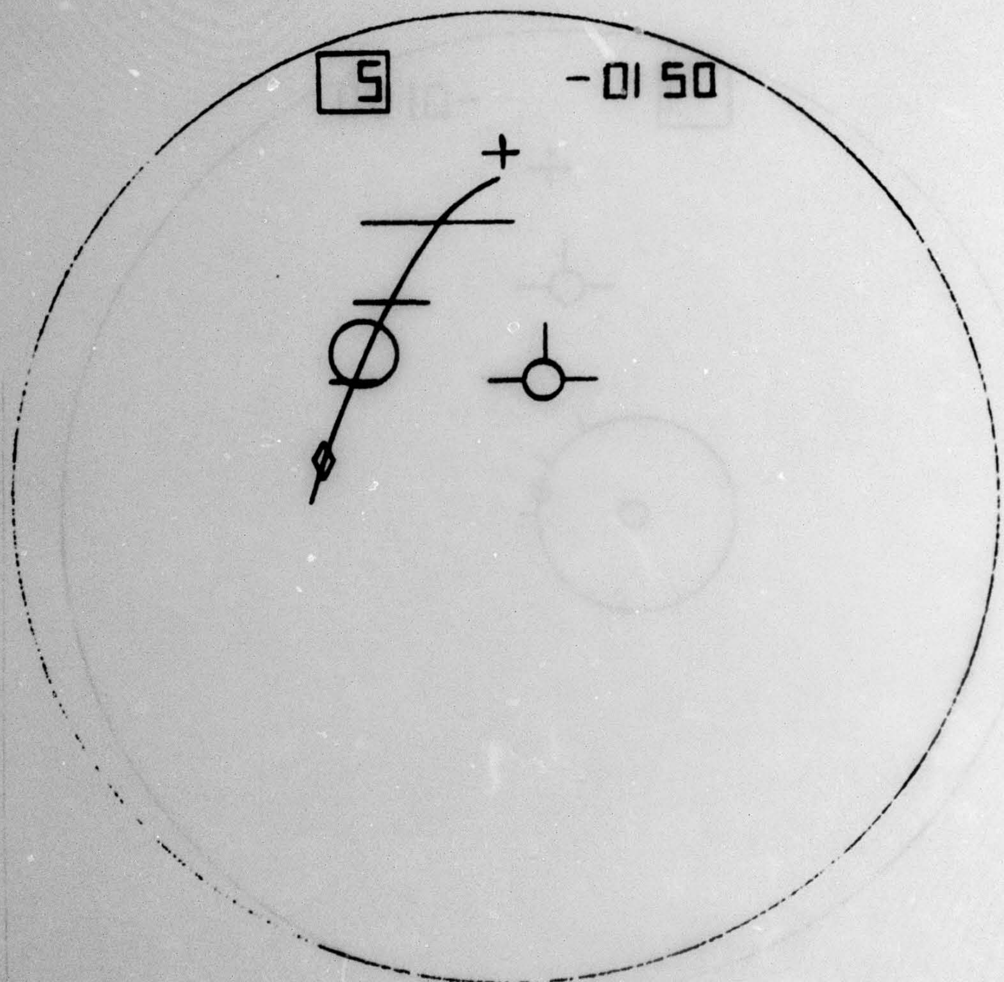
1. Gun Cross
2. Velocity Vector
3. Sight Reticle
4. Bomb Fall Line

The optional set includes:

1. Pitch Lines
2. Moveable Air Speed Scale
3. Moveable Altitude Scale

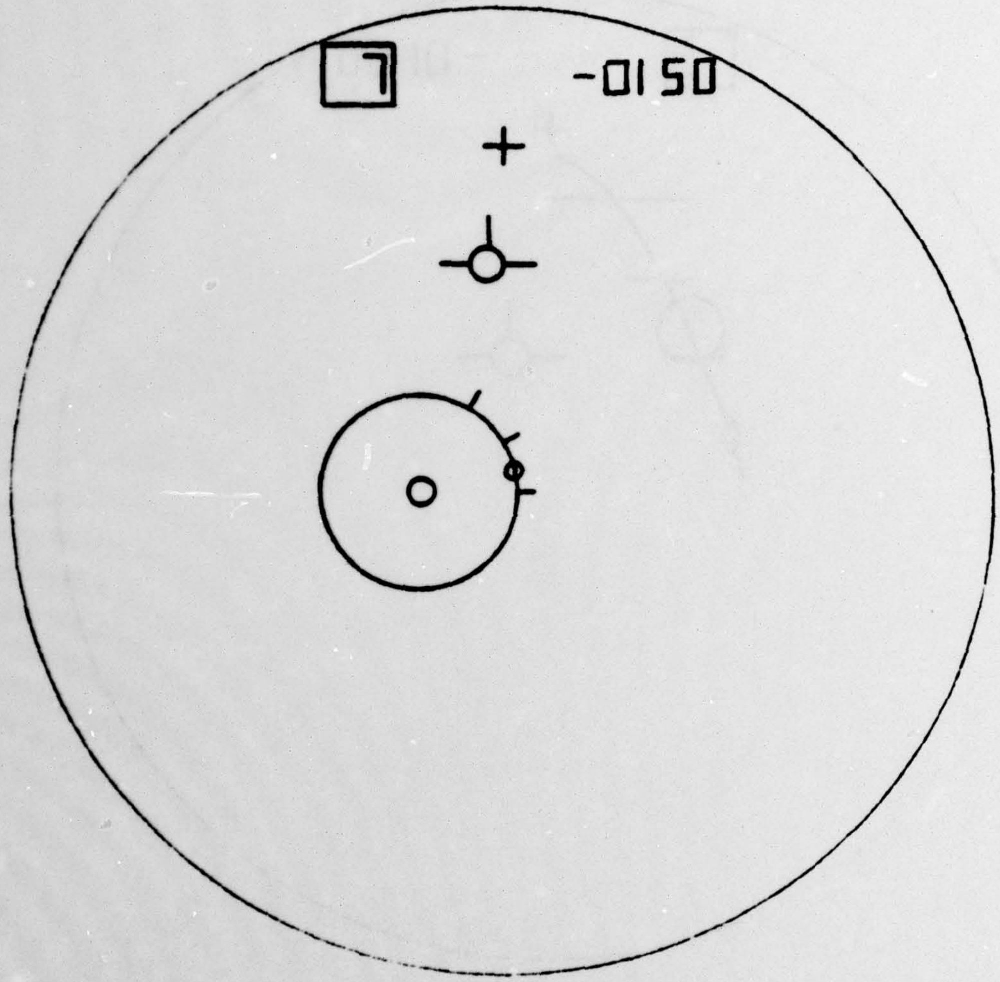
in addition to the standard set.

F. Test Pattern - Figure 7.



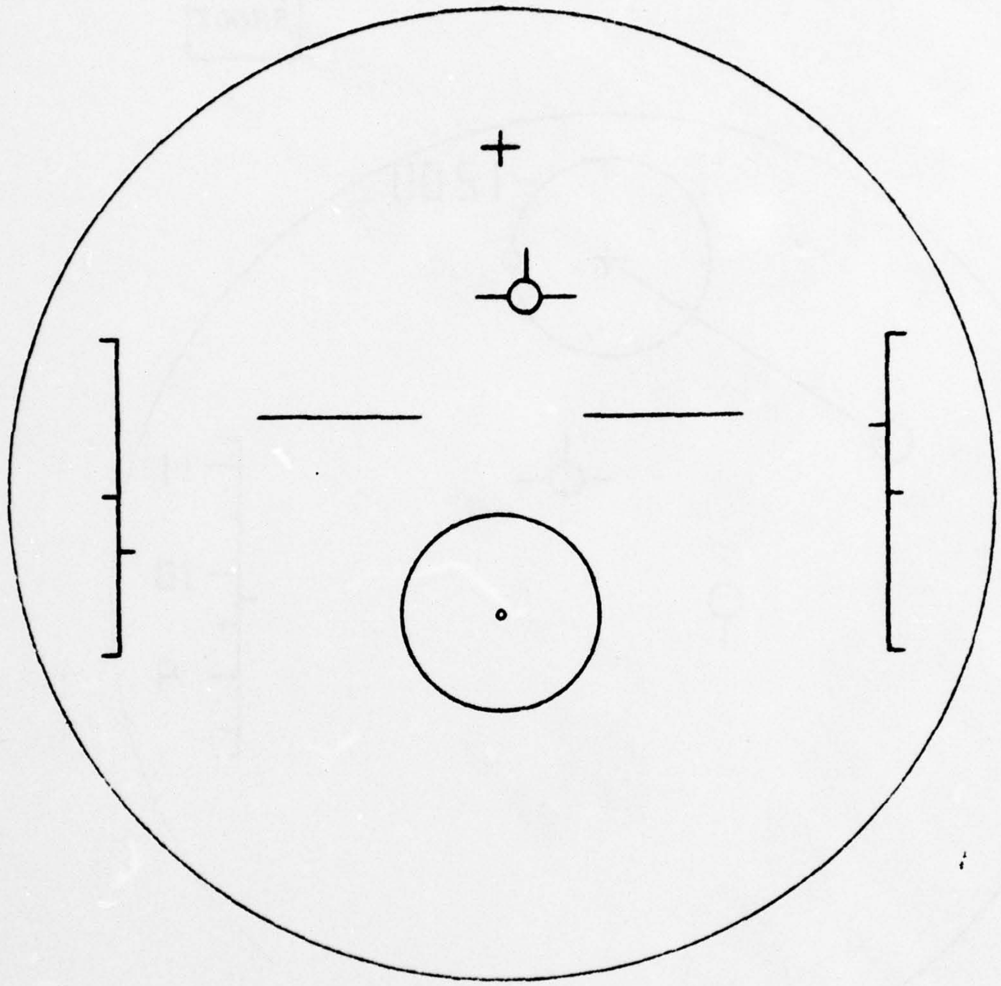
AIR TO AIR, GUNS
TRACER

FIGURE 2



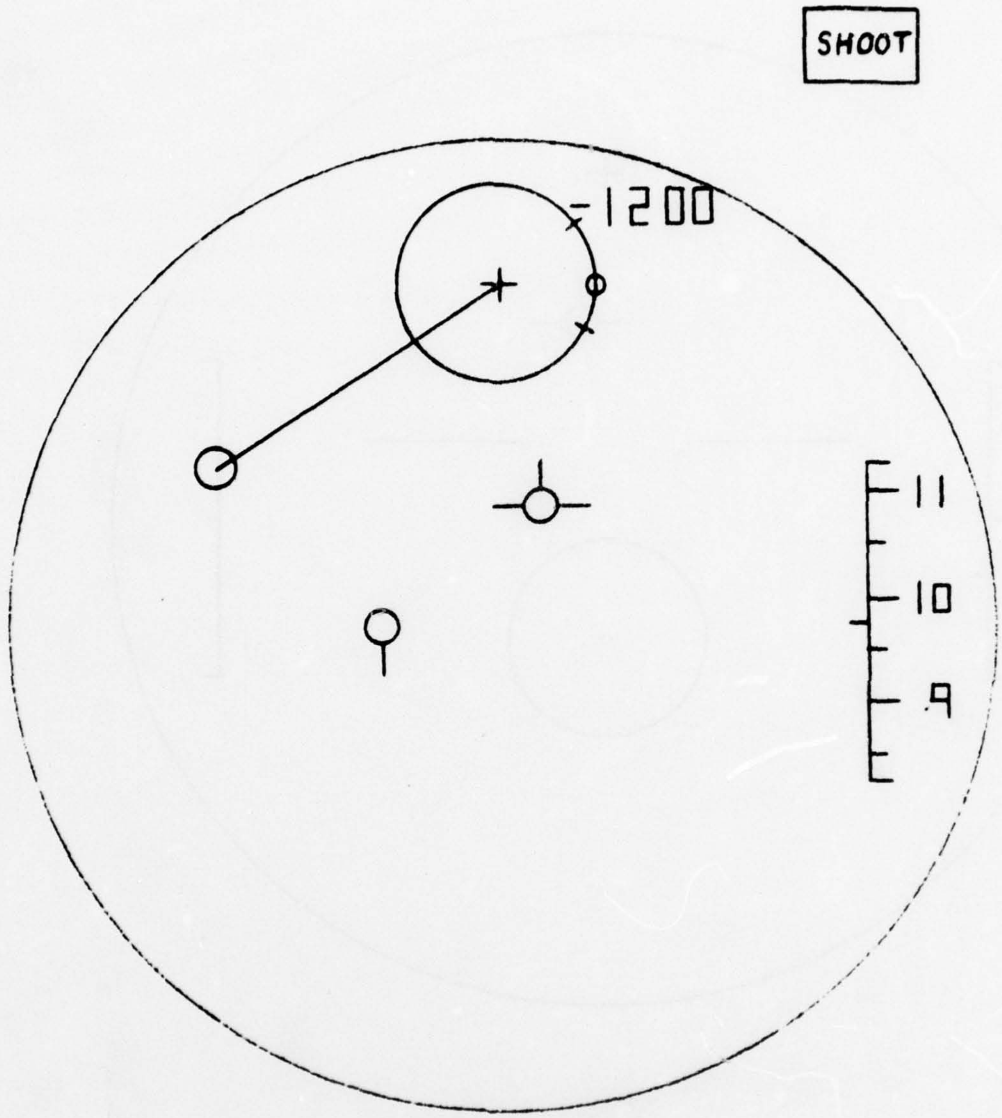
AIR TO AIR, GUNS
ALCOSS

FIGURE 3



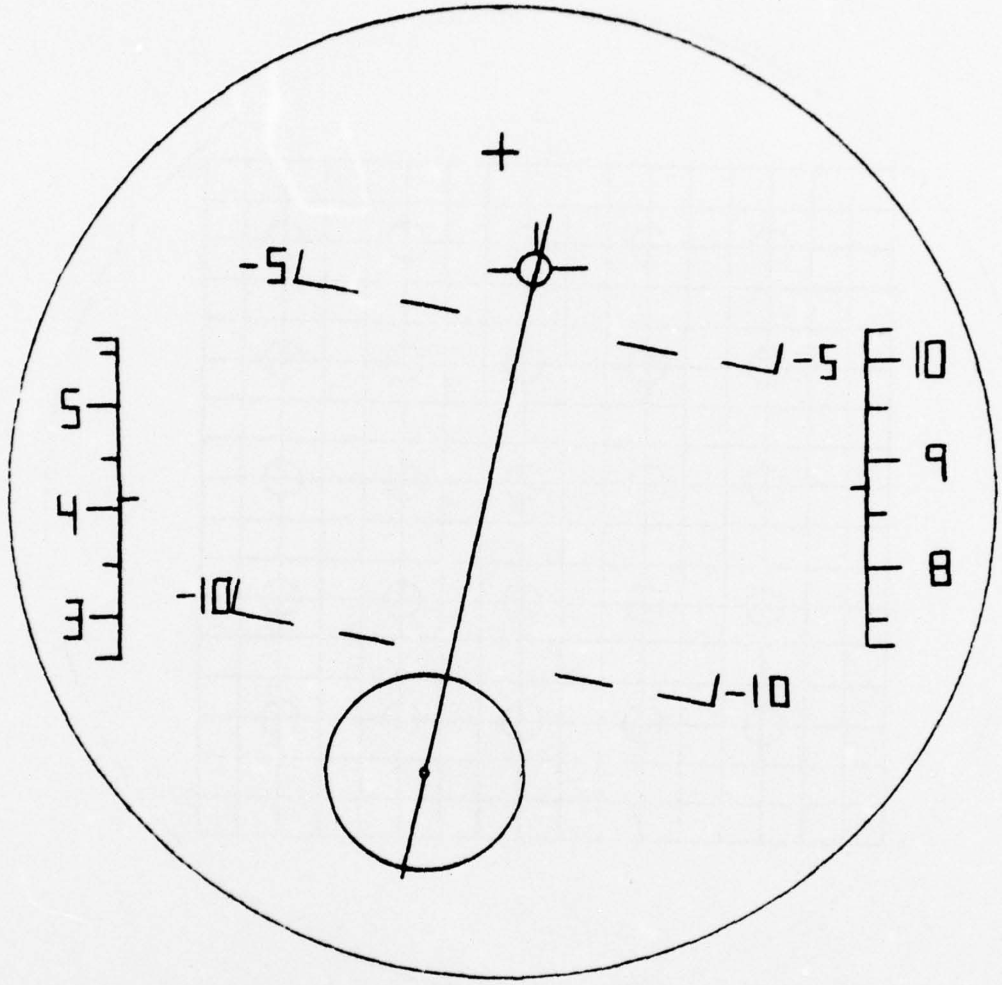
AIR TO GROUND, MANUAL

FIGURE 5.



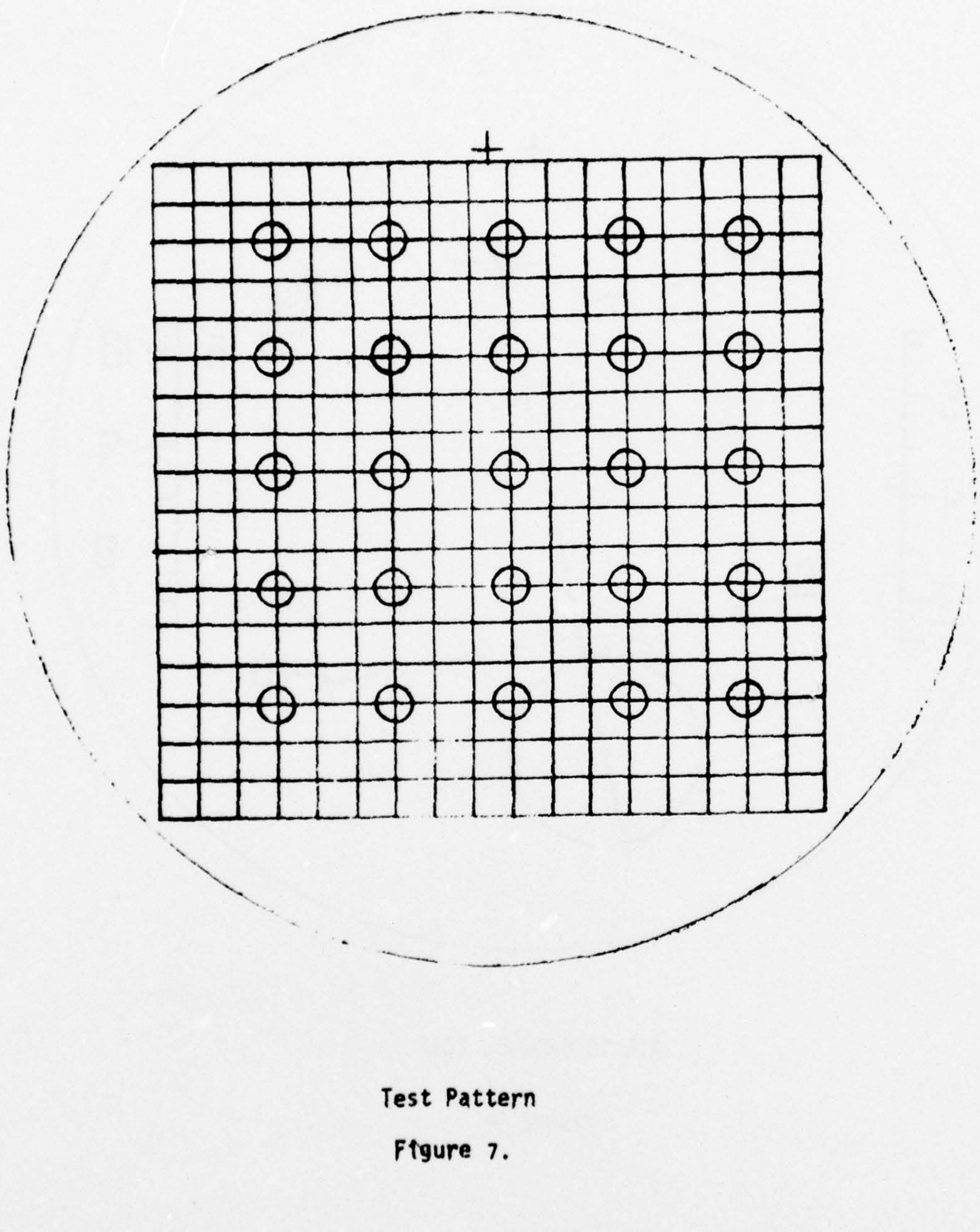
AIR TO AIR, MISSILE

FIGURE 4.



AIR TO GROUND, CCIP

FIGURE 6.



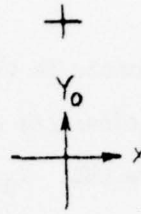
Test Pattern

Figure 7.

IV. Symbol Specifications

Specifications of the symbols in the various symbol groups are given in this section. The specifications are arranged in the five-word format required for transmission to the HUD. X_0, Y_0 and Z are given in milliradians in all cases. Equations for computing symbol parameters as a function of measured input parameters are included.

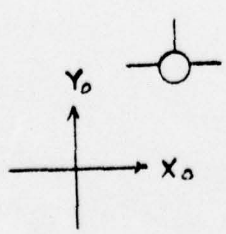
1. <u>Gun Cross</u>



	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Horizontal Line	-4	87.265	1.0	0	8
Vertical Line	0	83.265	0	1.0	8

2. <u>Velocity Vector</u>

	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Circle	B	A	4	4	4
Left Line	B-12	A	1.0	0	8
Vertical Line	B	A+4	0	1.0	8
Right Line	B+4	A	1.0	0	8



$\alpha = 87.265 - 17.453\alpha_T$, mr

$\beta = 228571 \dfrac{A_m}{\rho V a^2}$, mr

$V'_\ell = (V_N \cos C_A + V_E \sin C_A) \cos\theta - V_V \sin\theta$

$V'_m = (-V_N \sin C_A + V_E \cos C_A) \cos\phi$

$\quad + [(V_N \cos C_A + V_E \sin C_A) \sin\theta + V_V \cos\theta] \sin\phi$

$V'_n = (V_N \sin C_A - V_E \cos C_A) \sin\phi$

$\quad + [(V_N \cos C_A + V_E \sin C_A) \sin\theta + V_V \cos\theta] \cos\phi$

$V = \sqrt{(V'_\ell)^2 + (V'_m)^2 + (V'_n)^2}$, fps

V_N, V_E, V_V - Components of Ground Speed, fps

C_A, θ, ϕ - Heading, Pitch and Roll angles

	A	B
	α	β
All other modes		
Air-to-Ground - CCIP	$-\dfrac{V'_n}{V} 1000 + 122.15$	$\dfrac{V'_m}{V} 1000$

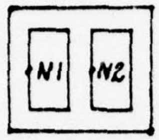
α_T - True Angle of Attack, Degree

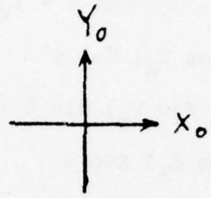
A_M - Lateral Acceleration, g's

ρ - Air Density, slugs/ft^3

V_a - fps

3. Rounds Remaining





	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Lower Line	-27.5	97.5	-1.0	0	17.5
Left Line	-45	97.5	0	1.0	15
Upper Line	-45	112.5	1.0	0	17.5
Right Line	-27.5	112.5	0	-1.0	15
10's Integer	-42.5	105	-	-	N1
1's Integer	-35	105	-	-	N2

$$N = N_L - (t + 0.75\ N_P)FR$$

10's Integer, N1 = INT $(\frac{N}{1000})$

1's Integer, N2 = INT $(\frac{N}{100})$ - 1000 N1

t = $\int$(Trigger 2) dt, seconds, Firing time

FR - Firing Rate, Rounds/Sec.

N_L = Initial magazine load, rounds

N_P = count of number of trigger depressions which have been executed.

4. <u>Range Rate</u>

— $\boxed{N1}$ $\boxed{N2}$ $\boxed{N3}$ $\boxed{N4}$

	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Sign	A1	105	1.0	0	5
1000's Normal	24	105	-	-	N1
100's Normal	31	105	-	-	N2
10's Normal	38	105	-	-	N3
1's Normal	45	105	-	-	N4

$\dot{R}$ - Range Rate, fps

$$N1 = INT\left(\frac{|\dot{R}|}{1000}\right)$$

$$N2 = INT\left(\frac{|\dot{R}|}{100}\right) - 10\ N1$$

$$N3 = INT\left(\frac{|\dot{R}|}{10}\right) - 10N2 - 100\ N1$$

$$N4 = INT\ |\dot{R}| - 10\ N3 - 100\ N2 - 1000\ N1$$

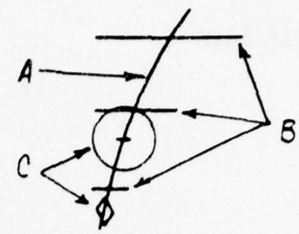
A1 = X_0 for sign given by following table.

IF	N1	> 0	0	0	0
	N2	-	> 0	0	0
	N3	-	-	> 0	0
A1		17	24	31	38
Do Not Display		-	N1	N1 N2	N1 N2 N3

For $\dot{R}$ > 0 Do Not Display Sign

5. <u>Air-to-Air Guns - Tracer</u>

A. <u>Tracer Line</u>



The tracer line program provides a table of 16 sets of line segment end point coordinates (15 lines) designated ψ_{Tn}, θ_{Tn}, n = 0, ..., 15. ψ and θ values correspond to X and Y coordinate excursions, respectively. These 15 lines represent the computed tracer line. The following equations are used to process the data supplied in the tracer line table into equivalent five word symbol element sets for transmission to the HUD.

Word 1	$X_{on} = \psi_{Tn}$	
Word 2	$Y_{on} = \theta_{Tn}$	
Word 3	$\left(\frac{\Delta X}{Z}\right)_n = \Delta X_{Tn}/Z_{Tn}$	
Word 4	$\left(\frac{\Delta Y}{Z}\right)_n = \Delta Y_{Tn}/Z_{Tn}$	
Word 5	$Z_n = Z_{Tn}$	n = 0,....,14

Where: $\Delta X_{Tn} = \psi_{Tn+1} - \psi_{Tn}$

$\Delta Y_{Tn} = \theta_{Tn+1} - \theta_{Tn}$

$Z_{Tn} = \sqrt{(\Delta X_{Tn})^2 + (\Delta Y_{Tn})^2}$

B. <u>Stadiametric Range Bars</u>

The tracer line program provides a table of 6 sets of line segment end point coordinates (3 lines) designated ψ_{Rn}, θ_{Rn}, n = 0, ..., 5. These lines represent three stadiametrically sized range bars at 1,000 ft, 2,000 ft. and 3,000 ft. The data in this table is processed to provide five word symbol sets as given in the following table.

	n	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1000' Range Bar	0	ψ_{R0}	θ_{R0}	1.0	0	Z_{R0}
2000' Range Bar	2	ψ_{R2}	θ_{R2}	1.0	0	Z_{R2}
3000' Range Bar	4	ψ_{R4}	θ_{R4}	1.0	0	Z_{R4}

Where: $Z_{Rn} = \psi_{Rn+1} - \psi_{Rn}$

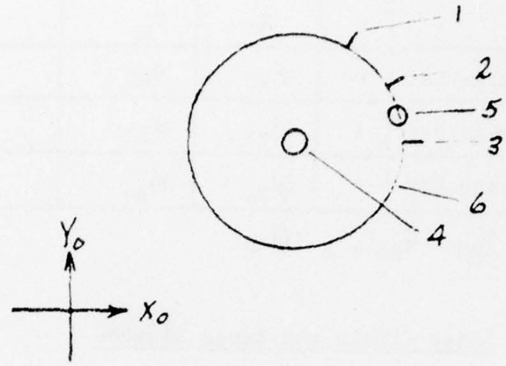
C. Range Circle and Range Diamond

The tracer line program provides a table of coordinates, ψ_c, θ_c, which locate a stadiametrically sized range circle on the tracer line at the range corresponding to the manual range input. It also provides three words (W1, W2, W3) which represent a set of X, Y coordinates and the radius of the stadiametrically sized range circle respectively. The X, Y coordinates represent the location of a diamond to be placed on the tracer line at the radar measured range of a target. The range circle or the diamond are displayed when Manual Mode or Radar Mode, respectively, are selected. These data are processed to provide five word symbol sets as given in the following table.

		X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Radar Range Diamond	Line 1	W1	W2-4	-.6	.8	5
	Line 2	W1-3	W2	.6	.8	5
	Line 3	W1	W2+4	.6	-.8	5
	Line 4	W1+3	W2	-.6	-.8	5
Manual Range Circle	Circle	Ψ_C	θ_C	W3	W3	W3
	Dash	Ψ_C-1	θ_C	1.0	0	2

6. **Air-to-Air Guns**

ALCOSS Reticle



	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. 1000 ft Range Bar	$X_H + \frac{A2}{2}$	Y_H + .86603A2	0.5	0.86603	4
2. 2000 ft Range Bar	X_H + .86603A2	$Y_H + \frac{A2}{2}$	0.86603	0.5	4
3. 3000 ft Range Bar	X_H + A2	Y_H	1.0	0	4
4. Inner Ring	X_H	Y_H	3	3	3
5. Present Range Circle	$X_H + A2\cos\theta_D$	$Y_H + A2\sin\theta_D$	2	2	2
6. Outer Ring	X_H	Y_H	A	A	A

X_H, Y_H supplied by ALCOSS Routine

θ_D = .03 R, deg.

Radar Mode: A2 = 25, mr

R = Radar Range, ft.

Manual Mode: $A2 = 500\frac{WS}{R}$, mr

R = R_{TH}, Thumbwheel (Stadiometric) Range

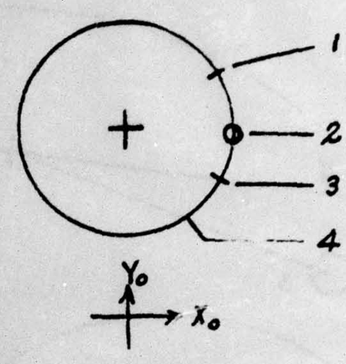
Fixed Range Mode: $A2 = \frac{WS}{3}$, mr

R = 1500 ft, fixed range

WS = Target Wing Span - feet

7. <u>Air-To-Air Missiles</u>

A. Fixed Reticle



	X_0	Y_0	$\frac{\Delta Y}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. R_{Min}	23 Sin θ_1	87.26 + 23 Cos θ_1	Sin θ_1	Cos θ_1	4
2. Present Range ⊙	25 Sin θ_2	87.26 + 25 Cos θ_2	2	2	2
3. R_{Max}	23 Sin θ_3	87.26 + 23 Cos θ_3	Sin θ_3	Cos θ_3	4
4. Fixed Reticle	0	87.26	25	25	25

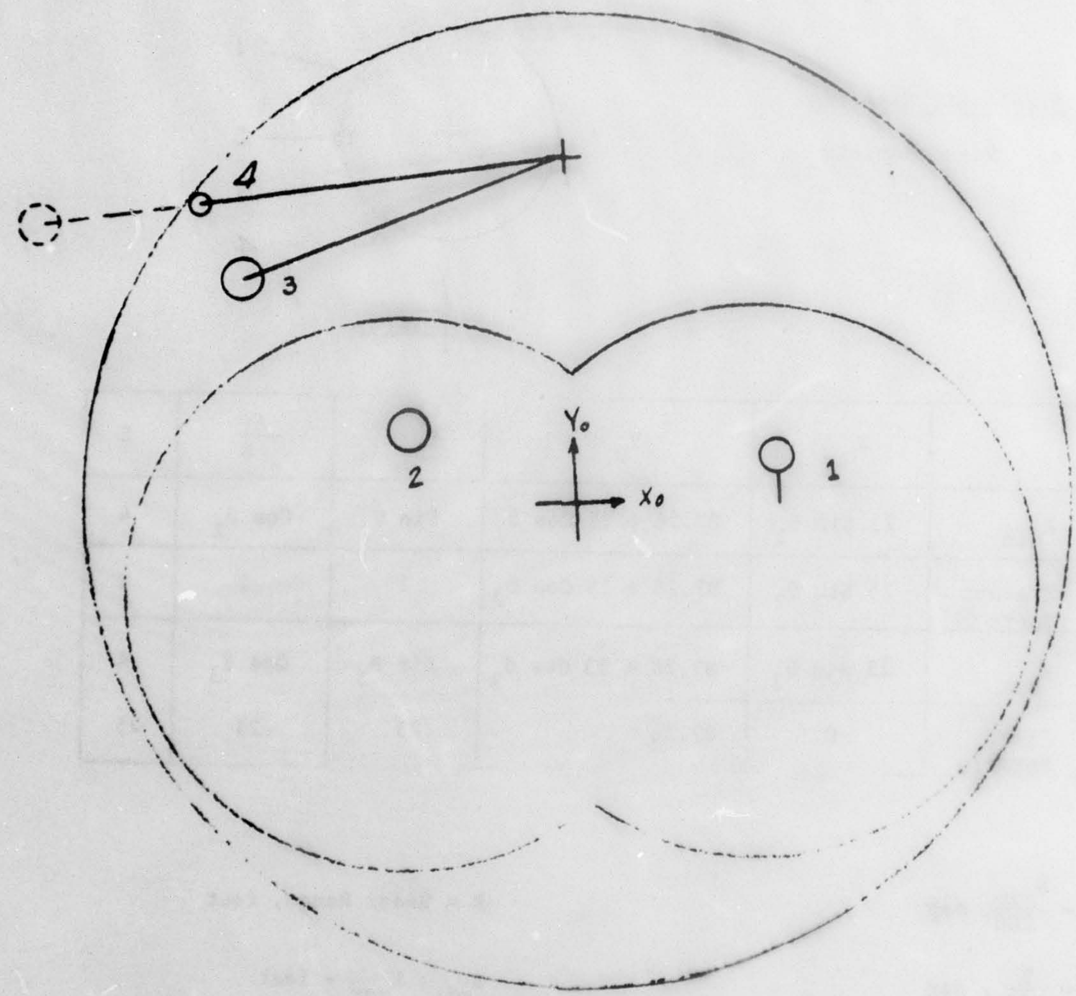
$\theta_1 = \frac{R_{min}}{100}$, deg

$\theta_2 = \frac{R}{100}$, deg

$\theta_3 = \frac{R_{max}}{100}$, deg

R = Radar Range, feet

R_{min}, R_{max} - feet



1. Steering Bug
2. Target designator, target within IFOV
3. Target designator, target within TFOV
4. Target designator, target outside TFOV

Figure 8

B. Steering Bug

$S = \sqrt{SEAZ^2 + SEEL^2}$, Deg.

$\text{Sin}\ \gamma = \frac{SEEL}{S}$ $\qquad$ $\text{Cos}\ \gamma = \frac{SEAZ}{S}$

$a = \alpha \cos \gamma - \beta \text{ Sin } \gamma$, mr

$b = \alpha \text{ Sin } \gamma + \beta \text{ Cos } \gamma$, mr

$r = \sqrt{14042 - a^2} - b$, mr

$S' = \frac{S}{7 + .8S}$ $\qquad$ Limit S' to: $S' \leq 1.0$

$S_r = S' r$, mr

$X_s = S_r \text{ Cos } \gamma + \beta$, mr

$Y_s = S_r \text{ Sin } \gamma + \alpha$, mr

	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Steering Bug Circle	X_s	Y_s	4	4	4
Steering Bug Tail	X_s	Y_s-4	0	-1.0	8

C. **Target LOS Designator**

	Q_1	Q_2	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Designator Circle	< 0	-	X1	Y1 + 87.265	5	5	5
	> 0	< 0	X1	Y1 + 87.265	5	5	5
	-	> 0	X2	Y2	2.5	2.5	2.5
Designator Line	< 0	-	**Delete Line**				
	> 0	< 0	0	87.265	Cos γ	Sin γ	C1
	-	> 0	0	87.265	Cos γ	Sin γ	C2

$X1 = 1000 \sin \lambda_a \cos \lambda_e$, mr

$Y1 = 1000 \sin \lambda_e$, mr

$Q1 = (|X1| - 43)^2 + (Y1 + 109.265)^2 - 4761$

$Q2 = (X1)^2 + (Y1 + 87.265)^2 - 13806$

$C1 = \sqrt{(X1)^2 + (Y1)^2}$

$\cos \gamma = \frac{X1}{C1}$; $\sin \gamma = \frac{Y1}{C1}$

$X2 = C2 \cos \gamma$, mr; $Y2 = C2 \sin \gamma + 87.265$, mr

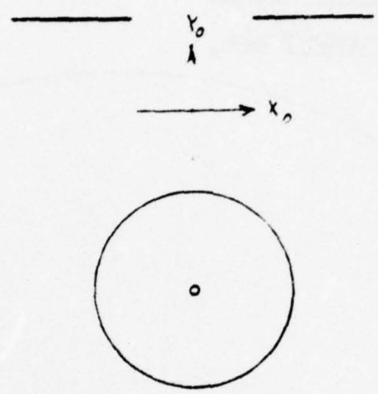
$C2 = -87.265 \sin \gamma + 117.5\sqrt{1 - .55075 \cos^2\gamma}$, mr

8. <u>Air-to-Ground</u>

<u>Manual</u>

A. <u>Ref. Pitch Line</u>

B. <u>Reticle</u>



	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Left line	-20	Y_p	-1.0	0	40
Right Line	20	Y_p	1.0	0	40
Pipper Circle	0	Y	1	1	1
Reticle Circle	0	Y	25	25	25

$Y = 122.5 + \text{SDA, mr}$

$Y_p = Y_p', \ |Y_p'| \leq 105, \text{ mr}$

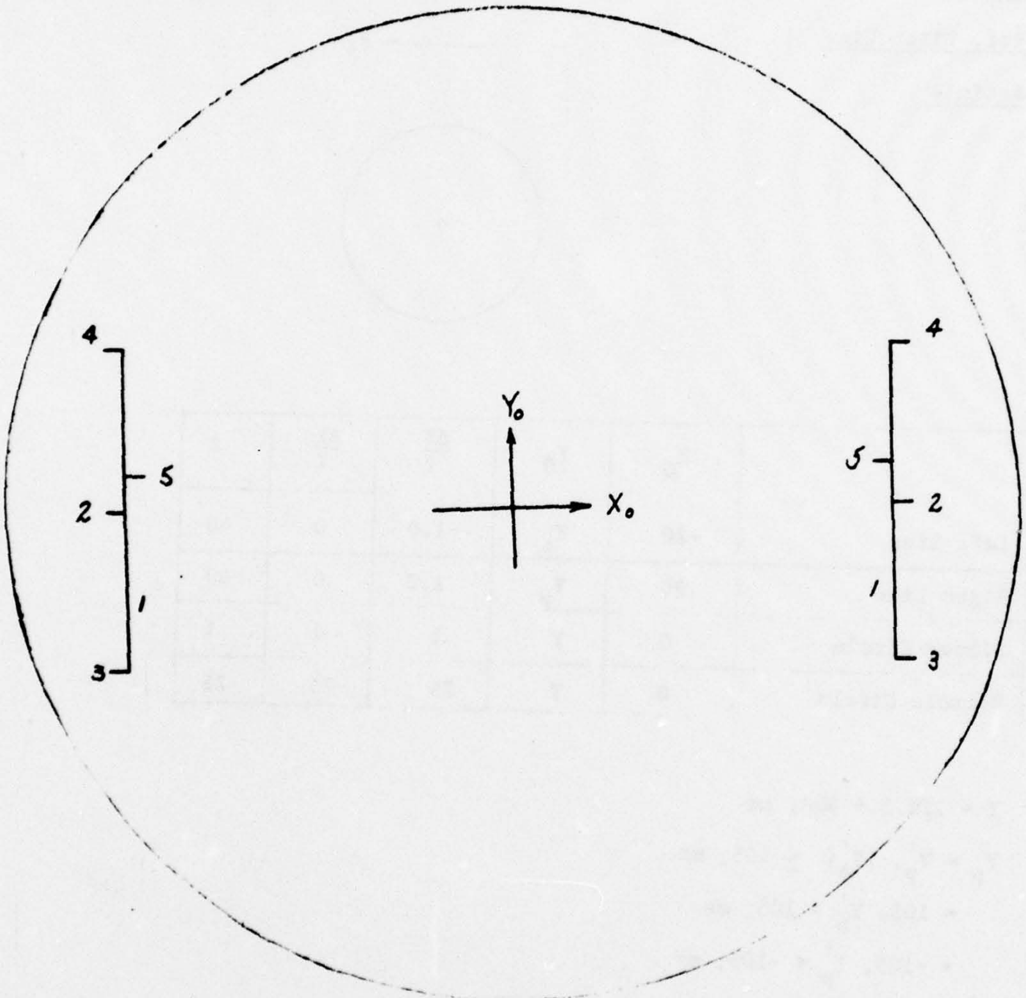
$= 105, \ Y_p' > 105, \text{ mr}$

$= -105, \ Y_p' < -105, \text{ mr}$

$Y_p' = [\theta_R^\circ - \theta^\circ + 5^\circ - \alpha_T^\circ](17.453), \text{ mr}$

C. Reference Air Speed Scale

D. Reference Altitude Scale



Reference Air Speed Scale

Reference Altitude Scale

Figure 9

C. <u>Reference Air Speed Scale</u>

True Air Speed Reference Scale	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. Vertical Line	-95	-40	0	1.0	80
2. Index	-95	0	-1.0	0	4
3. Lower Scale Limit	-95	-40	-1.0	0	4
4. Upper Scale Limit	-95	+40	-1.0	0	4
5. Relative Speed Pointer	-95	Y_{VR}	1.0	0	4

D. <u>Reference Altitude Scale</u>

Altitude Reference Scale	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. Vertical Scale Line	95	-40	0	1.0	80
2. Index	95	0	1.0	0	4
3. Lower Scale Limit	95	-40	1.0	0	4
4. Upper Scale Limit	95	+40	1.0	0	4
5. Relative Altitude Pointer	95	Y_{HR}	-1.0	0	4

$Y'_{VR} = (V_a - V_{aR}).8$

If: $Y'_{VR} - 40 > 0$, Then $Y_{VR} = +40$

If: $Y'_{VR} + 40 < 0$, then $Y_{VR} = -40$

Otherwise: $Y_{VR} = Y'_{VR}$

V_a - Knots

V_{aR} - Preset Release Airspeed, knots

$Y'_{HR} = (H - H_R)\ .04$

If: $Y'_{HR} - 40 > 0$, then $Y_{HR} = +40$

If: $Y'_{HR} + 40 < 0$, then $Y_{HR} = -40$

Otherwise: $Y_{HR} = Y'_{HR}$

H - Altitude, ft.

H_R - Preset Release Alt., feet

Air-to-Ground - Manual

Parameter Release Conditions for Manual Bomb Release

Parameter Value Conditions Selectable by Solution Number

Solution No.	1	2	3	4	5	6	7	8	9
θ_R, Deg	-60	-50	-45	-45	-40	-30	-40	-30	-20
SDA, Mils	-141	-174	-199	-160	-182	-201	-151	-192	-215
H_R, feet	6000	5000	5000	5000	5000	4000	5000	5000	4000
V_{aR}, Knots	350	350	350	400	400	400	450	450	450

θ_R - Reference Pitch Angle, Preset for Bomb Release

SDA - Preset Sight Depression Angle

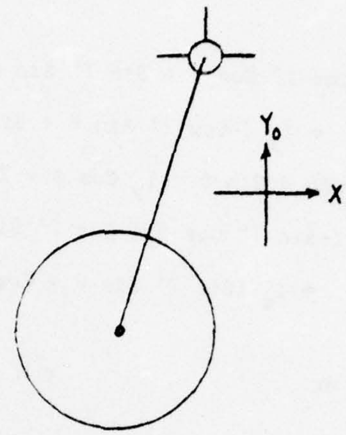
H_R - Reference Altitude, Preset for Bomb Release

V_{aR} - Reference TAS, Preset for Bomb Release

9 Air-to-Ground

A. CCIP Pipper

B. Bomb Fall Line



$$\begin{bmatrix} V'_{p\ell} \\ V'_{pm} \\ V'_{pn} \end{bmatrix} = \begin{bmatrix} Va \cos(\alpha^\circ_T + 2^\circ) + V_{E\ell} \\ Va \sin\beta + V_{Em} \\ Va \sin(\alpha^\circ_T + 2^\circ) + V_{En} \end{bmatrix}, \text{ fps}$$

$$\begin{bmatrix} V_{px} \\ V_{py} \\ V_{pz} \end{bmatrix} = \begin{bmatrix} V'_{p\ell} \cos\theta + V'_{pm} \sin\theta \sin\phi + V'_{pn} \sin\theta \cos\phi \\ V'_{pm} \cos\phi - V'_{pn} \sin\phi \\ -V'_{p\ell} \sin\theta + V'_{pm} \cos\theta \sin\phi + V'_{pn} \cos\theta \cos\phi \end{bmatrix}, \text{ fps}$$

$$H_T = H - h_T$$

$$t_f = -\frac{V_{pz}}{g} + \sqrt{\left(\frac{V_{pz}}{g}\right)^2 + \frac{2H_T}{g}}, \text{ sec., } g = 32.174 \text{ ft/sec}^2$$

$$W_x = V_x - V_{px} + V_{E\ell} \cos\theta + V_{Em} \sin\theta \sin\phi + V_{En} \sin\theta \cos\phi, \text{ fps}$$

$$W_y = V_y - V_{py} + V_{Em} \cos\phi - V_{En} \sin\phi, \text{ fps}$$

$$\begin{bmatrix} I_x \\ I_y \\ I_z \end{bmatrix} = \begin{bmatrix} V_x t_d + (V_{px} + W_x)\, t_f \\ V_y t_d + (V_{py} + W_y)\, t_f \\ H_T \end{bmatrix}, \text{ feet}$$

$$\begin{bmatrix} I_{H\ell} \\ \\ \\ I_{Hm} \\ I_{Hn} \\ \\ \end{bmatrix} = \begin{bmatrix} [I_x(\text{Cos } 7^\circ \text{ Cos } \theta + \text{Sin } 7^\circ \text{ Sin } \theta \text{ Cos } \phi) - I_y \text{ Sin } 7^\circ \text{ Sin}\phi \\ \quad + I_z (-\text{Cos } 7^\circ \text{ Sin } \theta + \text{Sin } 7^\circ \text{ Cos } \theta \text{ Cos } \phi)] \\ [I_x \text{ Sin } \theta \text{ Sin } \phi + I_y \text{ Cos } \phi + I_z \text{ Cos } \theta \text{ Sin } \phi] \\ [I_x (-\text{Sin } 7^\circ \text{ Cos } \theta + \text{Cos } 7^\circ \text{ Sin } \theta \text{ Cos } \phi) - I_y \text{ Cos } 7^\circ \text{ Sin } \phi \\ \quad + I_z (\text{Sin } 7^\circ \text{ Sin } \theta + \text{Cos } 7^\circ \text{ Cos } \theta \text{ Cos } \phi)] \end{bmatrix}$$

$$X = \frac{I_{Hm}}{I_{H\ell}} 1000, \text{ mr} \qquad Y = -\frac{I_{Hn}}{I_{H\ell}} 1000, \text{ mr}$$

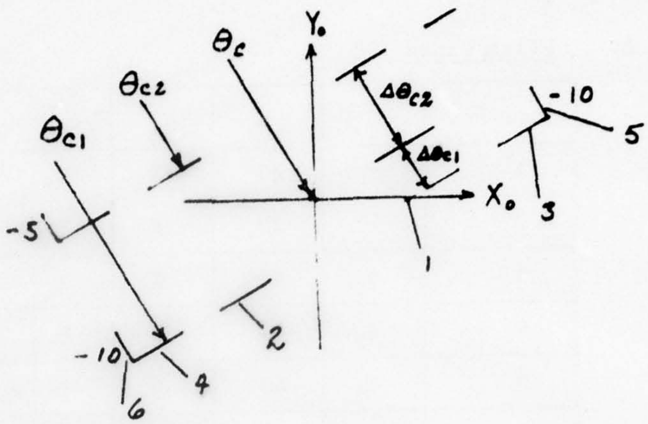
$$\Delta X = \beta - X, \text{ mr} \qquad \Delta Y = \alpha - Y, \text{ mr}$$

$$Z = \sqrt{(\Delta X)^2 + (\Delta Y)^2}, \text{ mr} \qquad V_{E\ell} = V_{Em} = 0$$

$$V_{En} = 7.5 \text{ fps}$$

	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
Pipper Circle	X	Y	1	1	1
Reticle Circle	X	Y	25	25	25
Bomb Fall Line	X	Y	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z

10. Pitch Lines and Tabs



$\sin \theta_C = \cos 7° \sin \theta - \sin 7° \cos \theta \cos \phi$

$\cos \theta_C = \sqrt{1 - \sin^2 \theta_C}$

$\sin \phi_C = \cos \theta \sin \phi / \cos \theta_C$

$\cos \phi_C = (\sin 7° \sin \theta + \cos 7° \cos \theta \cos \phi)/\cos \theta_C$

$\theta_C = \sin^{-1} (\sin \theta_C)$, radians

$\theta_{CI} = \mathrm{INT}\ (\theta_C/.087265)$

$\theta_{C1} = 87.265\ \theta_{CI}$, mr

$\theta_{C2} = \theta_{C1} + 87.265$, mr

$\Delta\theta_{C1} = \theta_{C1} - 1000\ \theta_C$, mr

$\Delta\theta_{C2} = \Delta\theta_{C1} + 87.265$, mr

$X = a \cos \phi_C + b \sin \phi_C$

$Y = a \sin \phi_C - b \cos \phi_C$

For θ_{CN}, $\Delta\theta_{CN}$: N = 1, for lower pitch lines.

N = 2, for upper pitch lines.

10's Integer: $N1 = \mathrm{INT}\left\{\left|\frac{\theta_{CN}}{174.53}\right|\right\}$

For N1 - 0, Do not display N1

1's Integer: $N2 = \mathrm{INT}\left\{\left|\frac{\theta_{CN}}{17.453}\right|\right\} - 10\ N1$

Do not Display sign if $\theta_{CN} > 0$

A. Pitch Lines

Line No.		a	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1	-	20	X	Y	Cos ϕ_C	Sin ϕ_C	z
2	-	-20	X	Y	-Cos ϕ_C	-Sin ϕ_C	z
3	q_2	46	X	Y	Cos ϕ_C	Sin ϕ_C	14
4	q_2	-46	X	Y	-Cos ϕ_C	-Sin ϕ_C	14
5	q_3	60	X	Y	q_1Sin ϕ_C	$-q_1$ Cos ϕ_C	8
6	q_3	-60	X	Y	q_1Sin ϕ_C	$-q_1$ Cos ϕ_C	8
$b = \Delta\theta_{CN}$							

B. Pitch Numerals

	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
10's Integer	X	Y	-	-	N1
1's Integer	X + 4.5	Y	-	-	N2
(-) Sign	X - 9.5	Y	1.0	0	5
a = 82, Right Numeral = -82, Left Numeral	$b = \Delta\theta_{CN} - 4q_1$				

Where:

θ_{CN}	q_1	q_2	q_3	z
> 0	+1	Delete	-	40
= 0	-	Delete	Delete	40
< 0	-1	-	-	14

C. <u>Pitch Line Blanking to Prevent Interference with Speed and Altitude Scales</u>

<u>Numerals</u>:

Delete corresponding numeral set if either test below is true:

Right Numeral Set: $X > 75.5$

Left Numeral Set: $X < -90$

<u>Pitch Lines</u>: Line Segments 1, 2, 3, 4

Delete right pitch tab, line 5, and substitute:

$$Z = \frac{85 - X_0}{(\Delta X/Z)}$$

for Z of Pitch Line 1 or 3 if following is true:

$$X_0 + Z\left(\frac{\Delta X}{Z}\right) > 85$$

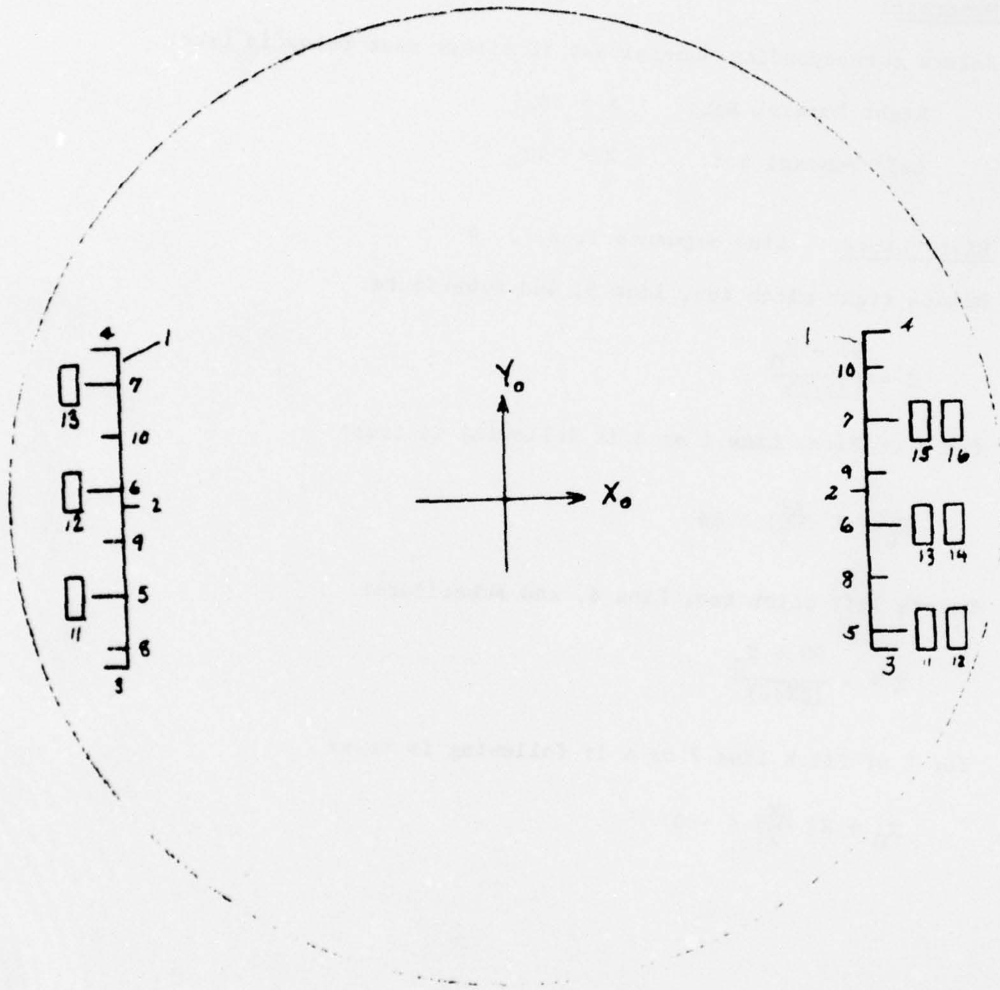
Delete left pitch tab, Line 6, and substitute:

$$Z = -\frac{90 + X_0}{(\Delta X/Z)}$$

for Z of Pitch line 2 or 4 if following is true:

$$X_0 + Z\left(\frac{\Delta X}{Z}\right) < -90$$

11. **Moveable TAS and Altitude Scales**



TAS Scale

Altitude Scale

Figure 10

A. Moveable TAS Scale

True Airspeed Scale	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. Vertical Scale	-95	-40	0	1.0	80
2. Index	-95	0	1.0	0	4
3. Lower Scale Limit	-95	-40	-1.0	0	6
4. Upper Scale Limit	-95	+40	-1.0	0	6
5. 1st Major Graduation	-95	Y_{V1}	-1.0	0	8
6. 2nd Major Graduation	-95	Y_{V2}	-1.0	0	8
7. 3rd Major Graduation	-95	Y_{V3}	-1.0	0	8
8. 1st Minor Graduation	-95	Y_{V4}	-1.0	0	4
9. 2nd Minor Graduation	-95	Y_{V5}	-1.0	0	4
10. 3rd Minor Graduation	-95	Y_{V6}	-1.0	0	4
11. 1st Numeral	-110	Y_{V1}	-	-	NV1
12. 2nd Numeral	-110	Y_{V2}	-	-	NV2
13. 3rd Numeral	-110	Y_{V3}	-	-	NV3

$\upsilon_D = \mathrm{INT}\left(\frac{V_a - 50}{100}\right)$, V_a in knots $\qquad Y_{V2} = Y_{V1} + \frac{80}{3}$, mr

$Y_{V1} = \left(\upsilon_D - \frac{V_a}{100}\right)\frac{80}{3}$, mr $\qquad Y_{V3} = Y_{V2} + \frac{80}{3}$, mr

$Y_{V4} = Y_{V1} - \frac{40}{3}$, $Y_{V2} < 0$ $\qquad Y_{V5} = Y_{V4} + \frac{80}{3}$, mr

$= Y_{V1} + \frac{40}{3}$, $Y_{V2} \geq 0$ $\qquad Y_{V6} = Y_{V5} + \frac{80}{3}$, mr

Do not display NV1 if $\upsilon_D < 0$

B. **Moveable Altitude Scale**

$$h_D = INT\left(\frac{H - 500}{1000}\right), \text{ H in feet}$$

$$Y_{H1} = \left(h_D - \frac{H}{1000}\right)\frac{80}{3}, \text{ mr}$$

$$Y_{H2} = Y_{H1} + \frac{80}{3}, \text{ mr}$$

$$Y_{H3} = Y_{H2} + \frac{80}{3}, \text{ mr}$$

$$Y_{H4} = Y_{H1} - \frac{40}{3}, \text{ mr, If } Y_{H2} < 0$$

$$= Y_{H1} + \frac{40}{3}, \text{ mr, If } Y_{H2} \geq 0$$

$$Y_{H5} = Y_{H4} + \frac{80}{3}, \text{ mr}$$

$$Y_{H6} = Y_{H5} + \frac{80}{3}, \text{ mr}$$

$NH1 = INT\left(\frac{|h_D|}{10}\right)$, Display 1st sign If $h_D < 0$

If NH1 = 0, Do not display

$NH2 = |h_D| - 10\ NH1$

$NH3 = INT\ \frac{|h_D + 1|}{10}$, Display 2nd sign If $(h_D + 1) < 0$

If NH3 = 0, Do not display

$NH4 = |h_D + 1| - 10\ NH3$

$NH5 = INT\ \frac{|h_D + 2|}{10}$, Dispaly 3rd sign If $(h_D + 2) < 0$

If NH5 = 0,Do not display

$NH6 = |h_D + 2| - 10\ NH5$

Altitude Scale	X_0	Y_0	$\frac{\Delta X}{Z}$	$\frac{\Delta Y}{Z}$	Z
1. Vertical Scale	90	-40	0	1.0	80
2. Index	90	0	-1.0	0	4
3. Lower Scale Limit	90	-40	1.0	0	6
4. Upper Scale Limit	90	40	1.0	0	6
5. 1st Major Graduation	90	Y_{H1}	1.0	0	8
6. 2nd Major Graduation	90	Y_{H2}	1.0	0	8
7. 3rd Major Graduation	90	Y_{H3}	1.0	0	8
8. 1st Minor Graduation	90	Y_{H4}	1.0	0	4
9. 2nd Minor Graduation	90	Y_{H5}	1.0	0	4
10. 3rd Minor Graduation	90	Y_{H6}	1.0	0	4
11. 1st Numeral	100	Y_{H1}	-	-	NH1
12. 2nd Numeral	107	Y_{H1}	-	-	NH2
13. 3rd Numeral	100	Y_{H2}	-	-	NH3
14. 4th Numeral	107	Y_{H2}	-	-	NH4
15. 5th Numeral	100	Y_{H3}	-	-	NH5
16. 6th Numeral	107	Y_{H3}	-	-	NH6
17. 1st Sign	100	Y_{H1}	1.0	0	4
18. 2nd Sign	100	Y_{H2}	1.0	0	4
19. 3rd Sign	100	Y_{H3}	1.0	0	4

12. Air Density

$\rho = .0023769 \exp[.809745(\ell nP - 3.398557)]$, slugs/ft^3

13. MACH No.

MACH No. $= V_a/1116.89 \exp[.095127566 (\ell nP - 3.398557)]$

14. Altitude

$H = 145447 [1 - \exp\{.190255132(\ell nP - 3.398557)\}]$, feet

P - Air Pressure in inches of Hg.

V_a - TAS, fps

APPENDIX A5

WADSP 1802 (AN/AYK-8)
PROGRAMMER'S MANUAL

October 1973

WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER
Baltimore, Maryland

TABLE OF CONTENTS

1. MACHINE DESCRIPTION

1.1 GENERAL

The Westinghouse Airborne Digital Signal Processor (WADSP 1802) is an 18-bit, fractional, two's-complement, stored-program, data processing unit.

The processing unit is composed of a program and data storage memory, an adder, several registers which provide a working storage, and control logic which decodes and executes instructions. With the exception of shifts, data transfer between registers is accomplished by serial transfer of 3-bit parallel bites. A definition of the working registers with appropriate abbreviations are presented in the following paragraphs.

Accumulator (AC) – 18 bits

The main register for processing of data, the AC is usually used to perform unary operations (shifting, testing, or transferring) on data and, in addition, normally contains one of the operands for binary operations (algebraic and logical), with the other operand coming from memory.

Block Register (BR) – up to 3 bits

This register is regarded as an extension of the address field of an instruction and allows the expansion of directly addressable storage from 4,096 words to 32,768 words.

Effective Address Register (EAR) – 15 bits

This register contains the address from which a memory operand will be fetched or into which a data word will be stored for memory accessing instructions. It may also define type and length of a shift, type of test to be performed during a skip instruction, or type of data transfer to be effected by a register transfer instruction.

Index Register (IX) – 15 bits

The contents of this register are added to the EAR, if indexing is specified, to permit dynamic address modification. The capability for incrementation and testing of the IX may provide control for looping or timing. The IX is also used to save the return point for a subroutine jump.

Instruction Counter (IC) – 15 bits

This register contains the address of the next memory location from which an instruction will be fetched for processing. It is incremented during the execution of each instruction and may be loaded to change the normal sequential execution of instructions.

Instruction Register (IRS) 5 bits

A non-programmable register, which is used to save the high-order 5 bits of each instruction during the execution of that instruction.

Memory Operand Register (MOR) – 18 bits

This register is used as a buffer storage register between the arithmetic/control unit and the memory, and contains data read out of, or to be written into, core memory. It is also used to transfer data to and from the I/O interface unit.

Multiply-Quotient Register (MQ) – 18 bits

This register may be used as an intermediate for data transfer between memory locations; for some instructions, it is also regarded as an extension of the AC. It contains the least significant half of the product after a multiply, and contains the quotient after a divide.

Carry Flip-Flop – 1 bit

The carry from bit 18 of the adder is saved in this flip-flop. It may subsequently be loaded or tested for use in double-precision computation.

Overflow Flip-Flop – 1 bit

This flip-flop is set when the arithmetic capacity of the 18-bit word has been exceeded. Depending upon the nature of the occurrence, this may mean that rescaling of variable data is required.

A functional block diagram depicting the primary data paths in the processor is shown in figure 1. The format of instruction and data words is shown in figure 2. The numbering of bits as shown, from right to left starting with 1, will be used throughout this manual. Also, the notation EAR1, for example, will be used to denote bit 1 of the EAR. Thus, AC18 is the sign bit of the accumulator.

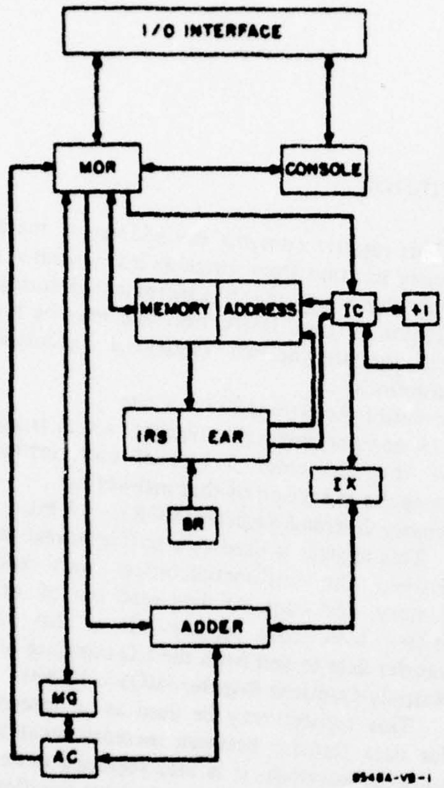


Figure 1. WADSP 1802 FUNCTIONAL BLOCK DIAGRAM

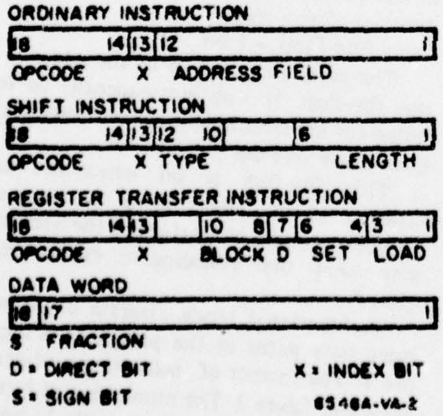


Figure 2. INSTRUCTION AND DATA WORD FORMAT

Each memory word is actually a 19-bit word, with 18 data bits and a memory protect bit (bit 19). If the bit is a 1, writing into the word is prevented by the memory control logic; if the bit is a 0, writing is allowed. (This feature may be overridden when ground support equipment is connected to the computer, as described in paragraph 1.4.)

The execution of an instruction is accomplished by the following sequence of steps.

- Step 1 – Instruction fetched from memory location specified by IC. High-order 6 bits of instruction to IRS, low-order 12 bits to low-order 12 bits of EAR; BR to 3 high-order bits of EAR (see figure 3). IC is incremented.
- Step 2 – If indexing is specified, EAR + IX is placed in EAR. IRS is decoded.
- Step 3 – If memory operand is required, it is fetched from address specified by EAR; if data is to be transferred to memory, it is stored in location specified by EAR. Otherwise, EAR is decoded (shifts, register transfer, skip) or placed in IC (jump).
- Step 4 – Any operations to be performed (algebraic, logical, etc) are completed using memory operand and AC contents.

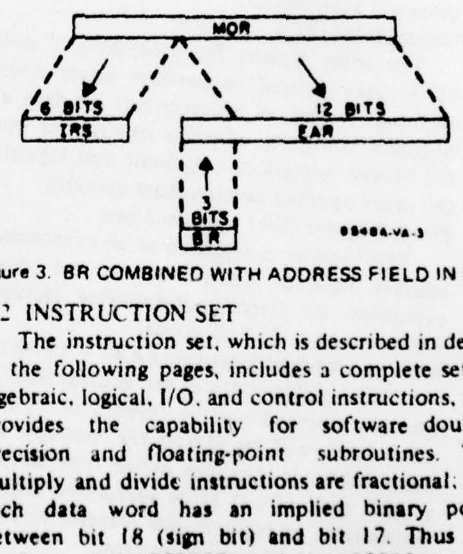


Figure 3. BR COMBINED WITH ADDRESS FIELD IN EAR

1.2 INSTRUCTION SET

The instruction set, which is described in detail in the following pages, includes a complete set of algebraic, logical, I/O, and control instructions, and provides the capability for software double-precision and floating-point subroutines. The multiply and divide instructions are fractional; i.e., each data word has an implied binary point between bit 18 (sign bit) and bit 17. Thus the product of ½ (200000) and ¼ (100000) is 1/8 (040000), and the quotient of 1/6 (052525) by 1/3 (125252) is ½ (200000), where the numbers in parentheses are octal representations of data words. For divides, the numerator must be less than the denominator to avoid divide overflow, which is not detected. Table 1 lists all computer operation codes, with corresponding mnemonics, instruction names, and page references.

TABLE 1.
COMPUTER INSTRUCTION CODES

Octal Code	Mnemonic	Name	Page
00	H	Halt	3
02	SH	Shift	3
04	DLN	Double Length Normalize	3
06	JS	Subroutine Jump	4
10	SK	Skip	4
12	–	Illegal	
14	J	Jump	4
16	SE	Select	4
20	RT	Register Transfer	5
22	SQ	Store MQ	5
24	SI	Store Index	5
26	ST	Store AC	5
30	–	Illegal	
32	–	Illegal	
34	–	Illegal	
36	I	Input	5
40	A	Add	5
42	CM	Compare Magnitude	5
44	S	Subtract	5
46	AI	Add to Index	5
50	LD	Load AC	5
52	LA	Load Absolute	6
54	N	Nand	6
56	AND	And	6
60	OR	Or	6
62	LQ	Load MQ	6
64	LI	Load Index	6
66	–	Illegal	
70	M	Multiply	6
72	D	Divide	6
74	JI	Jump Indirect	6
76	O	Output	6

HALT

00 | address	H	1.6 μsec
00 | address	HX	2.6 μsec

With ground support equipment disconnected, this instruction is executed as a no-op; i.e., decoding is performed and the instruction counter is incremented. With the ground console connected, an override is possible which causes the processor to discontinue instruction execution until a start signal is received from the console.

Registers altered: none

*n = shift length

SHIFT

02 | T | n	SH	1.6 + .2n μsec*
03 | T | n	SHX	2.6 + .2n μsec*

For single shifts, the AC alone is shifted; for double shifts, the AC and MQ are shifted as a 36-bit register. For right algebraic shifts, the AC is shifted with sign extension. For right logical shifts, zeroes are shifted into bit 18 of the AC. For left shifts, zeroes are shifted into bit 1 of the AC (single shifts) or bit 1 of the MQ (double shifts). For circular shifts, bit 1 of the AC (single shifts) or bit 1 of the MQ (double shifts) is shifted into bit 18 of the AC. If bit 18 of the AC is changed during the course of a left shift, the overflow flip-flop is set regardless of the final state of bit 18.

Mnemonic	T	Type of shift
DRL, DRLX	0	Double right logical
DRA, DRAX	1	Double right algebraic
DLL, DLLX	2	Double left logical
DRC, DRCX	3	Double right circular
SRL, SRLX	4	Single right logical
SRA, SRAX	5	Single right algebraic
SLL, SLLX	6	Single left logical
SRC, SRCX	7	Single right circular

Registers altered: AC and MQ, overflow flip-flop.
Note: Since indexing takes place on 12 bits of the address field, it is possible to change the type, as well as the length, of the shift by indexing.

DOUBLE LENGTH NORMALIZE

04 | address	DLN	3.4 + .2n μsec*
05 | address	DLNX	4.4 + .2n μsec*

The AC and MQ are shifted left as a 36-bit register until bit 18 of the AC is different than bit 17 of the AC, with zeroes being shifted into bit 1 of the MQ. The shift length is stored in the location specified by the effective address. If the AC and MQ both contain 0 initially, the shift length stored will be 0.

Registers altered: AC, MQ

SUBROUTINE JUMP

06 address	JS	2.2 μsec
07 address	JSX	3.2 μsec

After computation of effective address, the contents of the Instruction Counter, after incrementation, are placed in the Index Register and the effective address is placed in the Instruction Counter. Thus if the JS instruction is at locationX, the Index Register will contain X + 1 after completion of the instruction, and control will be transferred to the memory location specified by the effective address.
Registers altered: Index Register, Instruction Counter.

SKIP

		Skip/No Skip
10 address	SK	2.2/1.2 μsec
11 address	SKX	3.2/2.2 μsec

Each of bits 1-12 of the EAR defines a test condition, as specified below. A 12-bit test word exists in a set of flip-flops in the processor in which each bit is a 1 if the corresponding test result is true, 0 if it is false. If the logical product of the test word with the least significant 12 bits of the EAR is non-zero, the next instruction is skipped. Otherwise the next instruction is executed. Whenever bit 6 of the EAR is 1, the overflow flip-flop is reset to 0, regardless of its previous state.

Bit No.	Mnemonic	Definition
1	TSS 1	Sense Switch 1 on
2	TSS 2	Sense Switch 2 on
3	TSS 3	Sense Switch 3 on
4	TIZ	Index Register = 0
5	TC	Carry Flip-Flop = 1
6	TOV	Overflow Flip-Flop = 1 (resets Overflow Flip-Flop)
7	TE	Accumulator even
8	TGZ	Accumulator greater than 0
9	TEZ	Accumulator = 0
10	TLZ	Accumulator less than 0
11	TO	Accumulator odd
12	TIR	Input ready

Note: Indexing may affect the type of test to be performed. With ground support equipment disconnected, the TSS instructions will not skip.
Registers altered: Overflow Flip-Flop, Instruction Counter.

JUMP

14 address	J	2.2 μsec
15 address	JX	3.2 μsec

The 15-bit effective address is placed in the Instruction Counter causing control to be transferred to the location specified by the effective address.
Registers altered: Instruction Counter.

SELECT

16 address	SE	Timing dependent upon
17 address	SEX	I/O interface

The low-order 12 bits of the effective address are transmitted to the I/O interface to switch a multiplexer and initiate A-D conversion, if necessary, in preparation for transfer of digital data by the following input or output instruction.
Registers altered: none

REGISTER TRANSFER

20 address	RT	1.6 μsec
21 address	RTX	2.6 μsec

As defined below, effective address bits 1 through 7 specify a type of data transfer to be performed between the AC, EAR, Block Register, and Carry and Overflow Flip-Flops.

EAR Bit Set	Mnemonic	Description
1	LC	Carry Flip-Flop → AC1
2	LB	BR1,2,3 → AC2,3,4
3	LO	Overflow Flip-Flop → AC5
4	SC	AC1 → Carry Flip-Flop
5	SB	AC2,3,4 → BR1,2,3
6	SO	AC5 → Overflow Flip-Flop
7	SBD	EAR8,9,10 →BR1,2,3.

Registers altered: AC, Carry and Overflow Flip-Flops, Block Register.

STORE MQ

22 address	SQ	3.4 μsec
23 address	SQX	4.4 μsec

The contents of the MQ Register are transferred to the memory location specified by the effective address.
Registers altered: none.

STORE INDEX

24 address	SI	3.4 μsec
25 address	SIX	4.4 μsec

The contents of the 15-bit Index Register are stored, with sign extension, in the memory location specified by the effective address.
Registers altered: none

STORE AC

26 address	ST	3.4 μsec
27 address	STX	4.4 μsec

The contents of the Accumulator are stored in the memory location specified by the effective address.
Registers altered: none

INPUT

36 address	I	Dependent upon
37 address	IX	input interface

One data word is transferred from the interface unit to the location specified by the effective address.
Registers altered: none

ADD

40 address	A	3.2 μsec
41 address	AX	4.2 μsec

The two's - complement sum of the Accumulator contents and the memory operand is placed in the Accumulator. The carry (either 0 or 1) from bit 18 of the Adder is placed in the Carry Flip-Flop. If the algebraic sign of the final Accumulator contents differs from both the original Accumulator contents and the memory operand, the Overflow Flip-Flop is set. Otherwise, its state is unchanged.
Registers altered: AC, Carry and Overflow Flip-Flops.

COMPARE MAGNITUDE

		Skip/No Skip
42 address	CM	4.6/3.6 μsec
43 address	CMX	5.6/4.6 μsec

The absolute value of the Accumulator contents is subtracted from the memory operand. If the algebraic sign of the result is positive, the next instruction is skipped. If it is negative, no skip takes place. The Accumulator remains unchanged.
Registers altered: Instruction Counter.

SUBTRACT

44 address	S	3.2 μsec
45 address	SX	4.2 μsec

The two's complement of the memory operand is formed and added to the Accumulator contents. The sum is placed in the Accumulator and the Carry (either 0 or 1) from bit 18 of the Adder is placed in the Carry Flip-Flop. If the algebraic sign of the final Accumulator contents differs from both the original Accumulator contents and the complemented memory operand, the Overflow Flip-Flop is set. Otherwise, its state is unchanged.
Registers altered: AC, Carry and Overflow Flip-Flops.

ADD TO INDEX

46 address	AI	3.0 μsec
47 address	AIX	4.0 μsec

The 15-bit two's complement sum of the low-order 15 bits of the memory operand and the contents of the Index Register, is placed in the Index Register.
Registers altered: Index Register

LOAD ACCUMULATOR

50 address	LD	3.2 μsec
51 address	LDX	4.2 μsec

The memory operand is placed in the Accumulator.
Registers altered: Accumulator

LOAD ABSOLUTE

52 | address	LA	3.6 μsec
53 | address	LAX	4.6 μsec

If the memory operand is positive, it is placed in the Accumulator. If it is negative, its two's complement is placed in the Accumulator.
Registers altered: Accumulator

NAND

54 | address	N	3.4 μsec
55 | address	NX	4.4 μsec

The logical complement of the logical product of the Accumulator and memory operand is placed in the Accumulator.
Registers altered: Accumulator

AND

56 | address	AND	3.4 μsec
57 | address	ANDX	4.4 μsec

The logical product of the Accumulator and the memory operand is placed in the Accumulator.
Registers altered: Accumulator

OR

60 | address	OR	3.4 μsec
61 | address	ORX	4.4 μsec

The logical sum of the Accumulator contents and the memory operand is placed in the Accumulator.
Registers altered: Accumulator

LOAD MQ

62 | address	LQ	3.2 μsec
63 | address	LQX	4.2 μsec

The memory operand is placed in the MQ Register.
Registers altered: MQ

LOAD INDEX

64 | address	LI	3.0 μsec
65 | address	LIX	4.0 μsec

The low-order 15 bits of the Memory Operand Register are placed in the Index Register.
Registers altered: Index Register

MULTIPLY

		(min/avg/max)
70 | address	M	10.6/23.2/35.8 μsec
71 | address	MX	11.6/24.2/36.8 μsec

The fractional, two's-complement product of the Accumulator and the Memory Operand Register is formed. The most significant 18 bits of the 35-bit product are placed in the Accumulator, and the least significant 17 bits of the product are placed in the high-order 17 bits of the MQ Register. The least significant bit of the MQ is a 0.
Registers altered: Accumulator, MQ

DIVIDE

72 | address	D	34.4 μsec
73 | address	DX	35.4 μsec

A fractional, two's-complement divide is performed with the 36-bit contents of the AC and MQ forming the dividend, with the Memory Operand Register as the divisor. The quotient is placed in the MQ, the uncorrected remainder is placed in the AC. No overflow test is made.
Note: If the absolute value of the Accumulator contents is greater than the absolute value of the memory operand, overflow will occur, but will not be indicated.
Registers altered: Accumulator, MQ

JUMP INDIRECT

74 | address	JI	3.0 μsec
75 | address	JIX	4.0 μsec

The least significant 15 bits of the Memory Operand Register are placed in the Instruction Counter.
Registers altered: Instruction Counter

OUTPUT

76 | address	O	Dependent upon
77 | address	OX	output interface

The memory operand is transferred to the output interface.
Registers altered: none

1.3 INPUT/OUTPUT AND INTERRUPT

The requirements for interrupt and I/O multiplexing are problem dependent, and consequently the data processor is designed only to provide logic and instructions to service a single interrupt line and basic I/O channels.

An interrupt is serviced by storing the IC into location zero of the memory and loading the IC from location one. This transfers program control to the location previously stored in location one and provides the means for resuming the interrupted program at the address stored in location zero. The register transfer instruction provides a means of saving machine status (Carry and Overflow Flip-Flops, Block Register) and restoring it after the interrupt-servicing program is completed.

Should multiple interrupts be required, the I/O interface unit may be interrogated by means of a select instruction to determine the nature of the interrupt.

The select instruction provides the basic means of communicating with the I/O unit for input and output functions as well. The transfer of the low-order 12 bits of the EAR to the I/O unit will cause multiplexer switching to connect the desired input line and, if required for a specific input, initiate analog-to-digital (A/D) conversion. The digital data arising from the conversion are held in a register in the I/O unit to await the execution of an input instruction. Note that other computation may be performed while waiting for A/D conversion and the TIR (test input ready) instruction provides a means for the program to delay execution of the input instruction until conversion is finished. This is desirable, since execution of the input instruction (i.e., data transfer from the I/O holding register) may not be performed until conversion is completed. Thus the processor will be required to wait for conversion, causing effective decrease of processor speed.

For output functions, the select instruction is again used (the address field being decoded by the I/O unit) to do multiplexer switching, but conversion will now proceed independently of the processor after the transfer of data to the I/O unit (execution of output instruction). Thus no delays are required between select and output instructions.

1.4 GROUND SUPPORT EQUIPMENT

The ground support equipment (GSE) includes a paper tape reader from which programs may be loaded and a console (see figure 4), which provides the following capabilities:

- Manual input to registers and memory
- Sense switches to provide manual control of program branching
- Display of processor registers and memory contents

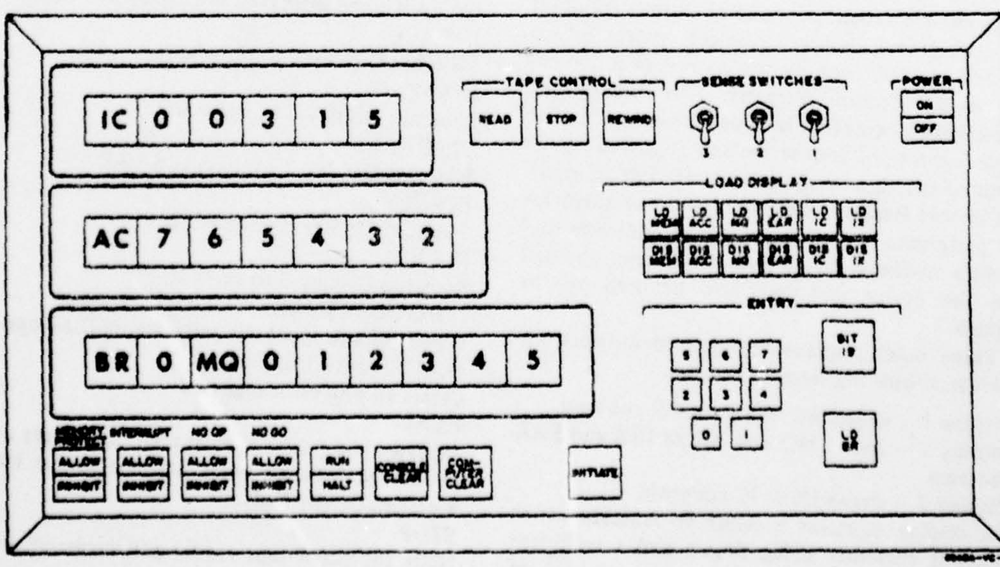


Figure 4. CONSOLE GROUND SUPPORT EQUIPMENT

- Program execution in normal (continuous) mode or manually initiated single instruction (stepped) mode.

Manual data insertion is accomplished by loading a Console Register (CR) through an octal keyboard and causing transfer of data from this register to a processor register by depressing an appropriate switch. Memory locations are loaded and displayed through the MOR. When loading or displaying memory, the EAR is incremented after each initiation, providing ease of loading or displaying segments of memory.

The console also includes the capability of interfacing with a Teletype ASR model 33, as well as permitting the use of the high-speed tape reader under program control. In order to minimize the hardware required in the interface, some logic control is required in the program to communicate with a peripheral device through the console, as described in the following paragraphs.

There is a set of discrete input lines running from the console to the computer, which may be sampled periodically to determine the status of the console peripheral interface. There are also discrete output lines used for control and data transmission. For the teletype and reader interface, eight lines represent data, and two lines represent control signals which indicate whether or not peripheral devices are ready for I/O.

To initiate either an input or output function on a peripheral device, a select instruction is executed and followed by the output of a control word to the Console Register. This informs the console which operation is to be performed. For an output operation, another select, followed by an output of the data word, is executed. For an input, the Console Register is sampled and examined for the "peripheral ready" signal, which indicates that the data on the input data lines has been updated from the device and may now be used by the program.

Three octal displays are used to indicate the contents of nine registers, as follows:

- Display 1 – shows AC, MEM, or CR contents
- Display 2 – shows MQ and BR or IRS and EAR contents
- Display 3 – shows IX or IC contents

Each display contains a letter to indicate which register is currently being shown and a sufficient number of octal digits to indicate the contents of that register (e.g., 6 for AC, 5 for XR, etc).

The switches present on the console, with their functional descriptions, are listed below:

POWER
Turns console power on or off.

INITIATE
In combination with RUN/HALT, initiates the processor in a stepped or continuous mode.

RUN/HALT
When depressed, halts the processor and places it in the single-step mode. Otherwise, the processor is in the continuous mode.

SS1, SS2, SS3
Sense switches

LD MEM
Cause the CR contents to be written into the location specified by the EAR.

LD EAR
Transfers data from CR to EAR.

LD ACC
Transfers data from CR to AC.

LD MQ
Transfers data from CR to MQ.

LD IX
Transfers data from CR to IX.

LD IC
Transfers data from CR to IC.

LD BR
Transfers data from CR to BR.

DIS MEM
Causes the contents of the location specified by the EAR to be displayed in Display 1.

DIS ACC
Switches Display 1 to show AC.

DIS MQ
Switches Display 2 to show MQ.

DIS EAR
Switches Display 2 to show IRS-EAR.

DIS IX
Switches Display 3 to show IX.

DIS IC
Switches Display 3 to show IC.

CONSOLE CLEAR
Clears (sets to zero) CR and console flip-flops.

COMPUTER CLEAR
Clears all processor registers.

READ
Initiates the paper tape reader and causes data to be loaded into memory, starting at the location specified by the EAR.

STOP
Halts the paper tape reader and suspends program loading.

AD-A042 255 WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 19/5
F-4E FIRE CONTROL SYSTEM SIMULATOR, F-4E AUSTERE/HEADS UP DISPL--ETC(U)
MAY 77 W PATTERSON F33615-74-C-1173

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AD
A042255

REWIND
Causes the paper tape reader to rewind the tape.

BIT 19
Changes the status of the 19th bit (memory protect bit) of the Console Register.

MEMORY PROT
In the ALLOW position, memory protect (described in paragraph 1.1) functions normally. In the INHIBIT position, memory protect is overridden and all memory writes are permitted.

INTER
In the ALLOW position, all interrupts connected to the computer are permitted to function normally. In the INHIBIT position, all interrupts are disconnected.

NO-OP
In the ALLOW position, operation code 00 (see paragraph 1.2) functions as a no-operation. In the INHIBIT position, the processor halts upon decoding this operation code.

NOGO
In the ALLOW position, all malfunction indications designed into the computer (voltage and temperature monitor circuits, attempted storage into protected location, etc) function normally. In the INHIBIT position, the computer continues operating in spite of a malfunction indication.

2. SOFTWARE PACKAGE

2.1 GENERAL

The software package for the WADSP 1802 includes four basic parts: (1) the assembler; (2) the simulator; (3) the output and formatting routines, and (4) the subroutine library. The first three of these are written for the UNIVAC 1108 computer, and are designed to interface with the EXEC II system on that computer; they provide a powerful means for generating and debugging programs for the WADSP. The subroutine library is a collection of frequently used programs for the WADSP 1802 which may be incorporated into an operational program and includes such programs as trigonometric, inverse trigonometric, and square root functions.

The block diagram in figure 5 depicts the generation of a program for the WADSP 1802 using the UNIVAC 1108 as an intermediate assembly, checkout, and preparation device.

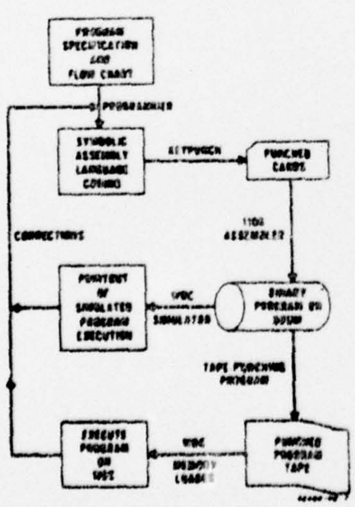


Figure 5. PROGRAM GENERATION USING UNIVAC 1108

The operational sequence of program preparation is described in the following steps.

- Step 1 – Programs are coded in the WADSP assembly language, described in paragraph 2.2, and punched on data processing cards.
- Step 2 – Using the assembler and simulator, the programs are checked out on the 1108, with changes and corrections being inserted in card form.
- Step 3 – When simulator checkout is completed, the output and formatting routines are used to prepare a punched tape containing a binary version of the program.
- Step 4 – Using the paper tape reader and console, the program is loaded into the WADSP 1802 for further checkout and test.

The following sections describe in detail the various parts of the software package and explain the use of each.

2.2 ASSEMBLY LANGUAGE

Programs for the WADSP are assembled by the UNIVAC 1108 assembler, which has been modified by referencing a set of procedures which define WADSP assembly language mnemonics for the 1108 assembler. A procedure (also referred to as a macro-operation, or macro, although technically distinct from a macro) is a device implemented in the 1108 assembler to allow definition of operations and, when used in generating programs for the WADSP, will usually generate one 18-bit instruction or data word. Further information on procedures may be found in UNIVAC 1108 manual UP-4042.

Because the 1108 assembler is used for WADSP program assembly, the WADSP assembly language is a modified subset of the 1108 assembly language and its syntax is the same. The assembler input is composed of cards, each of which is regarded as containing (at most) four fields, delimited by blanks. The four fields are the label field, the operation field, the operand field, and the comment field. A typical card is shown below.

LABEL blanks OPERATION blanks OPERAND blanks COMMENT

The label field begins in column 1 of a source card, and is ended by the first blank column encountered in reading from left to right. If column 1 is blank, no label is present on the line. A label is used to refer to a memory location or numeric value symbolically and is composed of no more than 6 nonblank characters, all of which must be alphameric, and the first of which must be alphabetic. The occurrence of a label in column 1 defines its value for that assembly, and should it occur more than once within a single assembly, an error flag will be generated. The label field may be preceded by / in column 1, which will cause a new page to be started by the printer.

The first nonblank character after the label field begins the operation field. An operation name, like a label, must contain at most 6 nonblank alphameric characters, the first of which is alphabetic. The operation may be a mnemonic for a WADSP machine instruction or may be any of the pseudo-operations described later in this section. If no operation is present, the operand, if present, must be an expression (defined below) and one data word will be generated containing the expression value. Like the label field, the operation field is terminated by a blank.

The operand field, which begins with the first nonblank character following the operation field, may be divided into subfields separated by commas, and is terminated by a blank character. Each subfield is composed of an expression (see definition below).

The comment field, which is ignored by the assembler, is begun by the blank terminating the operand field, or by the occurrence of a period followed by a blank in any previous field. The purpose of the comment field is to allow explanatory remarks to be included in the program, which describe the nature and purpose of the processing being performed.

A glossary of the terms employed in the preceding paragraphs as well as other terms to be used in the remainder of this manual is presented in table 2.

TABLE 2. ASSEMBLER TERMS

LABEL – A means of identifying a value or a line of symbolic coding. It consists of an alphabetic character which may be followed by up to five alphameric characters.

FIELD – One of up to four segments into which a symbolic line is divided by blanks.

LABEL FIELD – The first field of a line, begins in column 1 and ends with the first nonblank column.

OPERATION FIELD – The field following the label field, delimited by blanks, contains a mnemonic or pseudo-op name which, like a label, must contain only alphameric characters and begin with an alphabetic character.

OPERAND FIELD – Starts with the first nonblank character following the operation field, optionally divided into subfields, each containing an expression, delimited by commas.

COMMENT FIELD – Starts either with the blank terminating the operand field or with a period followed by a blank anywhere in a line.

OPERATOR – One of the characters or sets of characters + (plus), – (minus), / (divided by), * (multiplied by), ++ (OR-ed with), ** (AND-ed with), */ (shifted by), *– and *+ (negative and positive decimal exponentiation, respectively).

EXPRESSION – A series of items connected by operators, where an item is a label, a number, or a parenthesized expression.

NUMBER – A series of digits, which may be preceded by a plus or minus sign, and may contain a decimal point. If no decimal point occurs, the number is an integer. If the first digit of an integer is zero, the number is treated as an octal number. Otherwise, it is decimal (e.g., 017 = 15). If a decimal point occurs, it must be preceded and followed by at least one digit and the first digit must be nonzero; the number is then a floating point number.

LITERAL – An expression enclosed in parentheses without an adjacent operator. The assembler will generate a data word containing the expression value; the value assigned to the literal is the address of this data word. All literals will be located following symbolically generated code and duplicates will be eliminated. Literals are not used in generating operational programs.

REFLEXIVE ADDRESSING – The symbol $ has a special meaning to the 1108 assembler. Under some circumstances it may be necessary to code an instruction whose meaning is "load the contents of the following memory location in the accumulator." One method of accomplishing this would be the definition of a label on the following line and a

reference to that label as operand of the load instruction. To obviate the necessity for placing a label on every line to be thus referenced, the symbol $ may be employed in the following manner: for every word generated, whether data or instructions, the symbol $ has a value equal to the address of that word while the assembler is generating the word. For example a line specifying LOAD $+1 would result in the generation of the instruction to load the following word. The act of making the operand relative to the instruction being generated is known as reflexive addressing.

UNDEFINED LABEL – A label may be referenced (i.e., used in an operand expression) which is not defined within the program being assembled, but which is defined in another program to be loaded with this one. Such a label is called undefined and its occurrence is indicated by the assembler, but is not necessarily an error.

EXTERNALLY DEFINED LABEL – Normally labels are defined only within the program currently being assembled. However, when using separately assembled subprograms, it is necessary to make the definition of a label available to other programs. This is accomplished by appending an asterisk to the label when it is defined (i.e., when it appears in the label field of a symbolic line of coding).

Before presenting illustrations of the foregoing definitions and explanations, it is desirable to list the mnemonic operations and pseudo-operations defined by the set of procedures which make up the WADSP assembler. The distinction between operations (ops) and pseudo-operations (pseudo-ops) is that ops refer to machine instructions on a one-for-one basis, whereas pseudo-ops direct the assembler to perform certain processing on the data contained in the operand field. For each symbolic line containing an op mnemonic in the operation field, one instruction word is generated by the assembler. For each symbolic line containing a pseudo-op in the operation field, any number of words (including zero) of any type (instruction or data) may be generated, depending upon the pseudo-op employed.

The mnemonics for machine instructions recognized by the WADSP assembler are listed in table 3, with the corresponding instruction names. The instruction descriptions will be found in paragraph 1.2.

The pseudo-op mnemonics, with their definitions, are presented in table 4.

Table 3 and 4 do not include all operation and pseudo-operation mnemonics which may be employed with the 1108 assembler, but do include all those allowed in WADSP programming. For a complete understanding of the 1108 assembly language, and those features of it which are compatible with the WADSP procedures, the UNIVAC 1108 Assembler Manual (UP 4041) and the WADSP procedure listings may be consulted.

The following examples will serve to illustrate and clarify the previous exposition.

EXAMPLE 1

```
XLAB    LD    Y    LOAD  Y
```

Explanation – The line label is XLAB, the operation is Y, and the comment is LOAD Y. One machine instruction will be generated, with the operation code for a load instruction, and an address field containing the value of the label Y.

EXAMPLE 2

```
        SI    0.
```

Explanation – No label is present. The period followed by blank ends the line. An instruction will be generated to store the IX in location 0.

EXAMPLE 3

```
A       J          $+2
```

Explanation – Reflexive addressing is being used. During assembly of this instruction, the symbol $ has the value A, the location of this instruction. The coding generated is the same as that which would be generated if the operand were A + 2.

EXAMPLE 4

```
P       EQUALS          4095
        L               P
```

Explanation – The label P is assigned the value 4095. No storage is allocated. The second card would place the contents of location 4096 in the Accumulator.

TABLE 3. WADSP ASSEMBLER OPERATION MNEMONICS

Mnemonic	Octal Code	Instruction Name	Page
A	40	Add	5
AX	41	Add Indexed	5
AI	46	Add to Index	5
AIX	47	Add to Index Indexed	5
AND	56	And	6
ANDX	57	And Indexed	6
CM	42	Compare Magnitude	5
CMX	43	Compare Magnitude Indexed	5
D	72	Divide	6
DX	73	Divide Indexed	6
DLL	022	Double Left Logical Shift	3
DLLX	032	Double Left Logical Shift Indexed	3
DLN	04	Double Length Normalize	3
DLNX	05	Double Length Normalize Indexed	3
DRA	021	Double Right Algebraic Shift	3
DRAX	031	Double Right Algebraic Shift Indexed	3
DRC	023	Double Right Circular Shift	3
DRCX	033	Double Right Circular Shift Indexed	3
DRL	020	Double Right Logical Shift	3
DRLX	030	Double Right Logical Shift Indexed	3
H	00	Halt	3
HX	01	Halt Indexed	3
I	36	Input	5
IX	37	Input Indexed	5
J	14	Jump	4
JX	15	Jump Indexed	4
JI	74	Jump Indirect	6
JIX	75	Jump Indirect Indexed	6
JS	06	Subroutine Jump	4
JSX	07	Subroutine Jump Indexed	4
LA	52	Load Absolute	6
LAX	53	Load Absolute Indexed	6
LB	200002	Load AC with BR	4
LC	200001	Load AC with Carry	4
LD	50	Load AC	5
LDX	51	Load AC Indexed	5
LI	64	Load Index	6
LIX	65	Load Index Indexed	6
LO	200004	Load AC with Overflow	4
LQ	62	Load MQ	6
LQX	63	Load MQ Indexed	6
M	70	Multiply	6
MX	71	Multiply Indexed	6
N	54	Nand	6
NX	55	Nand Indexed	6
O	76	Output	6
OX	77	Output Indexed	6

TABLE 3. WADSP ASSEMBLER OPERATION MNEMONICS (Continued)

Mnemonic	Octal Code	Instruction Name	Page
OR	60	Or	6
ORX	61	Or Indexed	6
RT	20	Register Transfer	4
RTX	21	Register Transfer Indexed	4
S	44	Subtract	5
SX	45	Subtract Indexed	5
SB	200020	Set Block	4
SBD	200100	Set Block Direct	4
SC	200010	Set Carry from AC	4
SE	16	Select	4
SEX	17	Select Indexed	4
SH	02	Shift	3
SHX	03	Shift Indexed	3
SI	24	Store Index	5
SIX	25	Store Index Indexed	5
SK	10	Skip	4
SKX	11	Skip Indexed	4
SLL	026	Single Left Logical Shift	3
SLLX	036	Single Left Logical Shift Indexed	3
SO	200040	Set Overflow from AC	4
SQ	22	Store MQ	5
SQX	23	Store MQ Indexed	5
SRA	025	Single Right Algebraic Shift	3
SRAX	035	Single Right Algebraic Shift Indexed	3
SRC	027	Single Right Circular Shift	3
SRCX	037	Single Right Circular Shift Indexed	3
SRL	024	Single Right Logical Shift	3
SRLX	034	Single Right Logical Shift Indexed	3
ST	26	Store AC	5
STX	27	Store AC Indexed	5
TC	100020	Test Carry	4
TE	100100	Test AC Even	4
TGZ	100200	Test AC Greater than Zero	4
TGEZ	100600	Test AC Greater or Equal Zero	4
TIR	104000	Test Input Ready	4
TIZ	100010	Test Index Zero	4
TLZ	101000	Test AC Less than Zero	4
TLEZ	101400	Test AC Less or Equal Zero	4
TNZ	101200	Test AC Nonzero	4
TO	102000	Test AC Odd	4
TOV	100040	Test Overflow	4
TSS	100001/2/4	Test Sense Switch	4
TEZ	100400	Test AC Equal to Zero	4

TABLE 4. WADSP PSEUDO-OPERATION MNEMONICS

Mnemonic	Definition
END	Indicates to the assembler the end of symbolic input. It is physically the last card of each assembly, and neither label nor operand may be used with it.
EQUALS	For the duration of the assembly, the label (which is required) has the value of the operand in all expression evaluations.
FC	Two subfields are required in the operand field, the first of which is floating point, the second of which is integer. A data word is generated which consists of the fractional 18-bit two's-complement number obtained by scaling the first operand to the binary scale specified by the second (i.e., if x is the first, n is the second, then the fractional number $x/2^n$ is generated).
IC	The operand, which must be an integer, is entered as an 18-bit two's-complement integer data word.
SAVE	The number of locations specified by the (integer) operand value is reserved.
WDCASM	The complete set of WADSP mnemonics is made available to the 1108 assembler. If the program being assembled is physically the first in WADSP memory, the operand must be non-zero. Otherwise, the operand must be zero or omitted. The first line of each WADSP program must contain this pseudo-op in the operation field. This pseudo-op carries an implied PROTCT.
PROTCT	The memory locations following, until the occurrence of a UNPRCT pseudo-op, are protected by the setting of bit 19, the memory protect bit.
UNPRCT	The memory locations following, until the occurrence of a PROTCT pseudo-op, are unprotected and bit 19 is set to zero.
ADDR	The 15-bit address in the operand field is inserted as a data word.

EXAMPLE 5

```
        J       LAB
        SAVE    6
        LD      (5)
```

Explanation – After the jump instruction generated by card 1, 6 locations (initialized to zero) will be reserved before generating the load instructions specified by card 3, as a result of the SAVE pseudo-op on card 2. Note that the operand in card 3 is a literal. The assembler will generate a data word containing the integer value 5, place it with other literals at the end of the program, and insert the address of this data word in the address field of the load instruction generated by card 3.

EXAMPLE 6

```
. THIS LINE IS A COMMENT
```

Explanation – The period followed by blank begins the comment field. Thus the entire card contains only comments.

EXAMPLE 7

```
A3*     FC      3.0,2
        IC      -036
```

Explanation –– The label A3 on card 1 will be externally defined because of the asterisk appended and its definition will thus be available to other programs to be loaded with the current program. Card 1 will cause a fractional 18-bit data word containing $3/2^2 = 3/4$ to be generated (octal 300000). Card 2 will cause an integer two's-complement value to be generated (octal 777742). Note that the operand on card 2 is octal because of the leading zero and that the operand -30 would have produced the same result.

EXAMPLE 8

```
+ (A**(B*/4)
```

Explanation – Since no operation is present, a data word will be generated containing the value of the expression in the operand field. Because there is an operator adjacent to each set of parentheses in the expression, the parentheses specify algebraic

grouping rather than literals. The expression will be evaluated by first shifting the value of B left 4 places (right shifts are obtained by placing a negative number after the shift operator), then anding with the value of A.

EXAMPLE 9

	JI	OUT
OUT	ADDR	ERTN
	...	
ERTN*	SBD	1

Explanation – The location OUT contains the address of the SBD instruction. The * on the ERTN label in conjunction with the JI allows jumping from a routine in one block to a routine in any other block.

The assembler output is relocatable binary code in the standard format of the 1108 EXEC II operating system, as well as a printed listing. The relocatable binary code is stored on magnetic drum and may also be obtained in card form or put on magnetic tape. A description of this format may be found in the UNIVAC reference manuals.

The use of the assembler to generate programs for the WADSP 1802 is described in paragraph 2.6.

2.3 SIMULATOR

The simulator is a program written for the UNIVAC 1108 computer which a core image of WADSP 1802 memory and simulator control cards as input data. It operates upon the core image in exactly the same manner that the WADSP would operate, by fetching and decoding instructions and simulating the execution of WADSP instructions, modifying the core image and simulated internal registers appropriately. It is composed of two basic parts, a processor simulator, which is written in 1108 assembly language to obtain speed and efficiency of simulation, and an I/O interface simulator, which is written in FORTRAN to provide ease of modification of simulated multiplexing and scaling functions.

After the simulator and the WADSP programs to be simulated are loaded in 1108 core by the EXEC II system (the means of accomplishing this are described in paragraph 2.6), the simulator begins by reading control cards. It will continue to do so until an 1108 control card is encountered (in which case it will load the IC with 2) or until directed to begin simulation elsewhere by an X control card (control cards are defined later in this section). In either case, the simulation process begins with an instruction fetch from the WADSP core image, using the address specified by IC contents. Simulation will then proceed according to the steps described below. The designations IC, AC, XR, etc. refer to locations internal to the simulator which are used to represent the corresponding internal WADSP registers.

- Step 1 – Instruction fetched from WADSP core image location specified by IC; IC incremented.
- Step 2 – Control bits (the 18 bits remaining in the 36-bit 1108 word when the 18-bit WADSP word is stored in the least significant half) are examined for specification of trace, flow, dump, or similar function. Appropriate conversion and printout is performed.
- Step 3 – Instruction decoded and, if required, memory operand fetched. Time counter updated.
- Step 4 – Instruction simulation is performed.

The only output of the simulator is printed output and, if none is selected by control cards, and no I/O or select instructions are executed, there will be no output from the simulator except a direct printout of control cards read.

As in the WADSP assembly language, blanks are delimiters on simulator control cards and divide the card into fields. The number of fields on a card is limited only by the physical size of the card (80 columns). The first field, which starts in column 1, is the option field. All others are number fields, each of which may contain one subfield, or two subfields separated by a comma. The option field contains letters or an asterisk, each of which specifies a desired function to be performed for the current simulation or until overridden by later option specifications. Each subfield of each number field contains from one to twelve digits and defines either a location address in the WADSP core image (in which case no more than five octal digits are allowed), a maximum instruction count after which the simulator is to discontinue execution, or a location and clock specification. Except on Q and R cards, the occurrence of two subfields within a number field defines a core region, whose beginning address is the number in the first subfield, and whose final address is the number in the second subfield. Thus 100,100 specifies a region consisting of the single location 100 (octal), and

0,37777 specifies the region consisting of the entire WADSP core image.

Symbols allowable in the option field, with definitions of the functions they specify, are listed in table 5.

TABLE 5. SIMULATOR OPTIONS

Symbol	Option Definition
C	All number fields must specify regions; during simulation, when an instruction is executed in any of the specified regions, it is counted by opcode. When simulation is discontinued, a count of the number of executions of each machine instruction in the specified regions is printed.
D	All number fields must specify regions; when simulation is discontinued, an octal dump of all specified regions is printed out.
E	A single decimal number must be present; it represents the maximum number of instructions to be allowed before discontinuing simulation. This number is set to 100000 (decimal) if no E option is selected.
F	All number fields must specify regions; whenever a jump-type instruction (J, JI, or JS) is executed within these regions, a trace message will be printed indicating the transfer of control.
G	Whenever a halt opcode is encountered, it will be executed as a halt; otherwise, it is executed as a no-op.
H	All number fields must specify regions; whenever control is transferred within one of these regions, simulation will be discontinued, regardless of the instruction fetched.
I	A single decimal number must be present; it represents the number of microseconds to elapse between generation of interrupts. If this option is not selected, no interrupts will be generated.
J,K,L,M	All number fields must specify regions; these letters are used to specify independent core areas. When control is transferred within the area defined by one of these letters, the entire area will be dumped in octal form.
P	One region specification must be present; it represents the region to be punched on paper tape for loading in the WADSP memory. All characters to the right of the blank that delimits the region specification will be punched in even-parity label format at the beginning and end of the tape.
Q	Each number field must contain two subfields; the first specifies a location (octal), the second specifies a clock and must be one of the numbers 0, 1, 2, or 3. Whenever the instruction at one of the specified locations is executed, the difference between the simulated time and the selected clock time will be printed out.
R	Each number field must contain two subfields; the first specifies a location (octal), the second specifies a clock and must be one of the numbers 0, 1, 2, or 3. Whenever the instruction at one of the specified locations is executed, the selected clock will be set to the current value of the simulated time and a message will be printed to indicate that this has occurred.
S	All number fields must specify regions; if the program attempts to store in any of these regions, the store will be inhibited and a message will be printed to indicate the occurrence.
T	All number fields must specify regions; whenever an instruction is executed in any of these regions, a single line will be printed containing a dump of the contents of all programmable registers in octal and also in fractional decimal where applicable. In addition, accumulated simulated time will be printed in microseconds.

X A single number may be present; it specifies the initial value with which the instruction counter is to be loaded. If no number is present, the instruction counter is loaded with 2. This option initiates simulation.

***** No number fields are processed; control is transferred to the I/O simulator to read input data cards.

Blank No number fields are processed; this option is used to re-initiate processing after a simulated halt without changing any register contents.

Note: The symbols E, I, X, *, and blank must occur in column 1; no other options may appear on cards containing them. All other options may be mixed on a single card if the region specifications desired are the same.

The format of input data cards does not depend on the particular interface being simulated, although the data on them will vary with the configuration. To simulate a particular interface, a set of names, select codes, and associated scale factors for inputs and outputs are incorporated into a FORTRAN subroutine called INPUTS. Blanks delimit input specifications on the input data cards as on simulator control cards. Each input specification has the form Name = Value, with no intermediate blanks. If the number in the value field contains a decimal point, the value specified will be scaled and formed into a 18-bit word (in the same manner used by the I/O unit), which will be stored in the program until a new value is specified for that input. If no decimal point is present, the number will be interpreted as a direct octal representation of the input value. The occurrence of the word STOP on a card, followed by a blank, will cause control to be returned to the processor simulator.

Whenever a select instruction is executed by the simulator, a message is printed showing the 12-bit octal value sent to the I/O and the name of the input or output to which the multiplexer is switched by this value. When an input or output instruction is simulated, a message is printed showing the input or output name, octal value, and scaled (real-world) value. Use of the simulator is described further in paragraph 2.6.

2.4 PREPARATION OF TAPE

When a punched tape is desired to load a WADSP program into the processor itself, the P option is used. The tape-punching program, which is loaded into 1108 memory with the WADSP core image and the simulator, reformats the core image and writes it on a magnetic tape for later punching of tape on a peripheral device. The magnetic tape format is dependent on the peripheral device to be used. The paper tape format accepted by the WADSP paper tape reader, however, is as shown in figure 6.

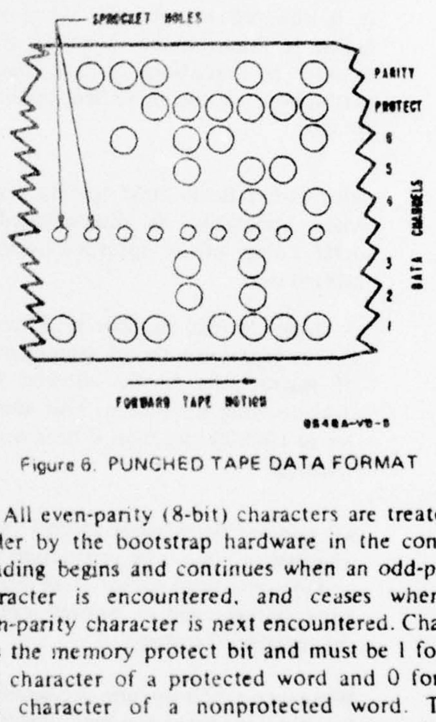


Figure 6. PUNCHED TAPE DATA FORMAT

All even-parity (8-bit) characters are treated as leader by the bootstrap hardware in the console. Loading begins and continues when an odd-parity character is encountered, and ceases when an even-parity character is next encountered. Channel 7 is the memory protect bit and must be 1 for the last character of a protected word and 0 for the last character of a nonprotected word. Three consecutive 6-bit characters (channels 1-6) are packed in the console register to form an 18-bit word, which is then transferred to the WADSP memory. A punched bit position represents a 1, a nonpunched position represents a 0. As the tape moves forward, the WADSP third-words read are high-order, middle, and low-order. Thus figure 6 shows the WADSP words 512137, 416601, and 410001 as they would appear on paper tape.

2.5 SUBROUTINE LIBRARY

The following paragraphs describe the subroutines available with the WADSP 1802. All are

referenced by coding a JS instruction, with the subroutine name in the operand field. The times given are approximate because of variation due to internal branching. All times are in microseconds.

SINE

SINE computes the sine of an angle in radians scaled to a maximum value of π by using a modified power series truncated to 4 terms. The result is scaled to a binary exponent of 0.

- Arguments: One, taken from the AC.
- Results: One, loaded in the AC.
- Locations Required: 50.
- Timing: Approximately 170 μsec.

COSINE

COSINE computes the cosine of an angle in radians scaled to a maximum value of π by generating an equivalent angle and using SINE. The result is scaled to a binary exponent of 0.

- Arguments: One, taken from the AC.
- Results: One, loaded in the AC.
- Locations Required: 7 + SINE.
- Timing: Approximately 170 μsec.

SQRT

SQRT computes the square root of the double-precision contents of the AC and MQ registers, using once-iterated Newton-Raphson approximation.

- Arguments: One double-precision, loaded in AC and MQ.
- Results: One, loaded in the AC.
- Locations Required: 44
- Timing: Approximately 160 μsec.

ARCTAN

ARCTAN computes the arctangent of a number, scaled to a binary exponent of zero by using a modified power series truncated to 4 terms. The result is scaled to a maximum value of π in radians and lies between $+\pi/4$ and $-\pi/4$.

- Arguments: One, taken from the AC.
- Results: One, loaded in the AC.
- Locations Required: 45
- Timing: Approximately 210 μsec.

ARCTN2

Given X and Y coordinates, ARCTN2 computes the polar angle of the point (X, Y). Arguments may be scaled to any binary exponent, as long as it is the same for both. The result is an angle, in radians, scaled to a maximum value of π in the range $+\pi$ to $-\pi$.

- Arguments: Two, X coordinate taken from AC and Y coordinate taken from MQ.
- Results: One, loaded in the AC.
- Locations required: 28 + ARCTAN
- Timing: Approximately 280 μsec.

ARCSIN

ARCSIN computes arcsine of a number x scaled to a binary exponent of 0 by using the formula: arcsine (x) = arctangent $(x/(1-x^2)^{1/2})$. The result is in radians, scaled to a maximum value of π and lies in the range between $+\pi/2$ and $-\pi/2$.

- Arguments: One, taken from AC.
- Results: One, loaded in AC.
- Locations Required: 14 + ARCTN2.
- Timing: Approximately 510 μsec.

ARCCOS

ARCCOS computes arccosine of a number x scaled to a binary exponent of 0 by using the formula: arccosine(x) = arctangent $((1-x^2)^{1/2}/x)$. The result is in radians, scaled to a maximum value of π and lies in the range between 0 and π.

- Arguments: One, taken from AC.
- Results: One, loaded in AC.
- Locations Required: 15 + ARCTN2.
- Timing: Approximately 510 μsec.

2.6 USE OF WADSP SOFTWARE PACKAGE

This paragraph describes the 1108 EXEC II system control cards, which are necessary in order to use the assembler, simulator, and output routines for the WADSP 1802, and the arrangement of decks for a typical 1108 run. A complete set of cards for a simulation run is depicted in figure 7. A description of the cards and decks shown in the figure is given in the following paragraphs.

RUN CARD – Precedes every run; contains accounting information and indicates to the EXEC II system that a new run is about to begin. The form of this card is:

@ RUN Number, Name, Time, Pages

where NUMBER is an accounting number, NAME is the programmer's name, TIME is estimated 1108

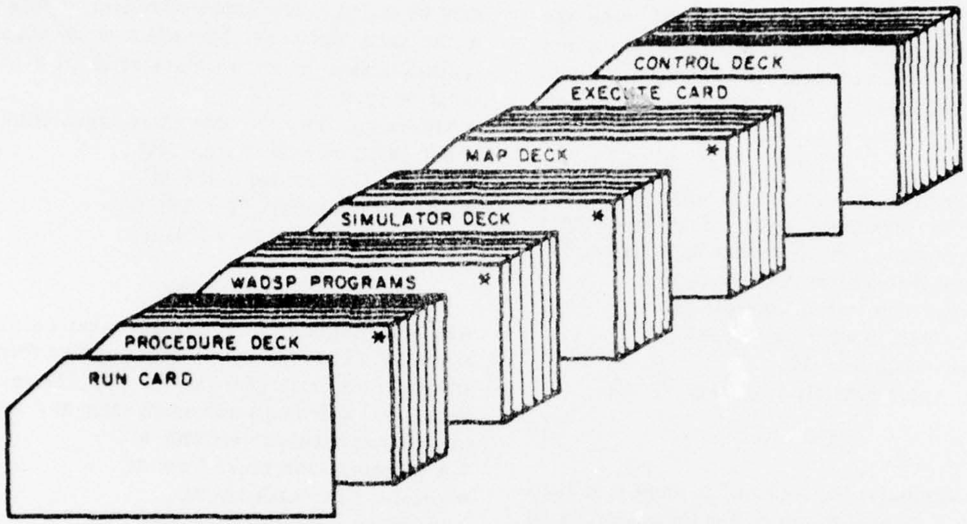


Figure 7 DECK ARRANGEMENT FOR WADSP SIMULATION RUN ON UNIVAC 1108

running time in minutes, and PAGES is the maximum number of printed pages of output expected.

PROCEDURE DECK Provided as part of the WADSP 1802 software package, this contains the procedures required to define the WADSP mnemonics for the 1108 assembler.

WADSP PROGRAMS Programs are of two types: (1) relocatable binary punched by the assembler after previous assemblies, and (2) symbolic programs to be assembled. Each symbolic program present must be preceded by a card requesting assembly, which has the form

```
@     ASM   Name
```

where NAME is the name of the program being assembled. If relocatable binary punched output is desired, a P should be punched in column 2.

SIMULATOR DECK Provided as part of the WADSP 1802 software package, this deck contains the WADSP simulator in relocatable binary or symbolic form.

MAP DECK Contains information for the EXEC II loader which enables the proper loading of the simulator and WADSP core image in 1108 memory. The form of this deck is shown below.

```
@            MAP   WADSP
DSP          SEG   SIM
             FIX   DSP,,0140000
MEMORY       SEG   Name1 - Name2 - ....Namen
             FIX   MEMORY,,0100000
```

The first card calls on the 1108 Memory Allocation Processor (MAP) to process the following cards. The second card specifies that an additional program (the simulator) called SIM is also to be loaded into a core segment called DSP, which is fixed by card 3 to have an internal data area starting at location 140000 (octal). The fourth card (which may not contain blanks between $Name_1$ and $Name_n$) instructs the loader to collect WADSP programs with names $Name_1$, $Name_2$, ..., $Name_n$ and put them into a core segment called MEMORY, which is fixed by card 5 to start at 1108 location 100000 (octal). The MAP deck shown will allow simulation of up to 16384 words of WADSP core memory. Larger memories may be simulated, but it is necessary to modify the MAP deck.

EXECUTE CARD – Instructs the 1108 EXEC II system to load and execute the WADSP simulator, as specified by the MAP deck. The form of this card is

```
@      XQT      WADSP
```

CONTROL DECK – Made up of WADSP simulator control cards (described in paragraph 2.3), contains specification of options and input values. This deck will be read by the simulator to control the simulation process. If no X control card is present, simulation will start at location 2.

Further details on the 1108 control cards and the memory allocation processor may be found in the EXEC II operating system description, UNIVAC Manual No. UP-4058.

ASSEMBLY LANGUAGE

Programs for the WADSP are assembled by a FORTRAN assembler which runs on either a Univac 1108 or IBM 7094 computer. The assembler input is composed of cards, each of which is regarded as containing (at most) four fields, delimited by blanks. The four fields are the label field, the operation field, the operand field, and the comment field. A typical card is shown below.

LABEL blanks OPERATION blanks OPERAND blanks COMMENT

The label field begins in column 1 of a source card, and is ended by the first blank column encountered in reading from left to right. If column 1 is blank, no label is present on the line. A label is used to refer to a memory location or numeric value symbolically and is composed of no more than 12 nonblank characters, all of which must be alphameric, and the first of which must be alphabetic. The occurrence of a label in column 1 defines its value for that assembly, and should it occur more than once within a single assembly, an error flag will be generated. The label field may be preceded by / in column 1, which will cause a new page to be started by the printer.

The first nonblank character after the label field begins the operation field. An operation name must contain at most 6 nonblank alphameric characters, the first of which is alphabetic. The operation may be a mnemonic for a WADSP machine instruction or may be any of the pseudo-operations described later in this section. If no operation is present, the operand, if present, must be an expression (defined below) and one data word will be generated containing the expression value. Like the label field, the operation field is terminated by a blank.

The operand field, which begins with the first nonblank character following the operation field consists of an expression and is terminated by a blank character.

The comment field, which is ignored by the assembler, is begun by the blank terminating the operand field, or by the occurrence of a period followed by a blank in any previous field. The purpose of the comment field is to allow explanatory remarks to be included in the program, which describe the nature and purpose of the processing being performed.

A glossary of the terms employed in the preceding paragraphs as well as other terms to be used in the remainder of this manual is presented in table 1.

TABLE 1 ASSEMBLER TERMS

LABEL - A means of identifying a value or a line of symbolic coding. It consists of an alphabetic character which may be followed by up to eleven alphameric characters.

FIELD - One of up to four segments into which a symbolic line is divided by blanks.

LABEL FIELD - The first field of a line, begins in column 1 and ends with the first nonblank column.

OPERATION FIELD - The field following the label field, delimited by blanks, contains a mnemonic or pseudo-op name which must contain only alphameric characters and begin with an alphabetic character.

OPERAND FIELD - Starts with the first nonblank character following the operation field and consists of an arithmetic expression.

COMMENT FIELD - Starts either with the blank terminating the operand field or with a period followed by a blank anywhere in a line.

OPERATOR - One of the characters or sets of characters + (plus), - (minus), / (divided by), * (multiplied by), ++ (OR-ed with), ** (AND-ed with), */ (shifted by) and .. (shifted by).

The operators and their hierarchy of execution are defined in table 2. Normal rules for evaluating expressions apply. That is, the innermost expression enclosed in parentheses is evaluated first and the evaluation proceeds to the outermost. In the absence of grouping (by parentheses) the sequence of operations is from left to right (see table 2). Operations

Hierarchy of Execution	Operator	Function
1	..	Scaling (or Shifting)
1	*/	Scaling (or Shifting)
2	-	Unary-minus
3	*	Multiplication
3	/	Division
4	+	Addition
4	-	Subtraction
5	**	Logical product
6	++	Logical sum

TABLE 2

involving the level-1 operator (scaling) are evaluated first, followed by evaluation of operators of levels 2,3,4,5 and 6. If the value of the expression is in the floating point mode, it will be truncated to the range of $-1 < V < 1$ where V is the fractional portion of the floating point result. V, then, becomes the value stored if the operand is a literal or appeared on a DATA card.

The following table shows the legal expression forms, where F stands for floating point expression and I stands for an integer expression:

Operation form	Result is	Operation form	Result is
F*/I	F	I/I	I
I*/I	I	F+F	F
-F	F	F+I	F
-I	I	I+F	F
F*F	F	I+I	I
F*I	F	F-F	F
I*F	F	F-I	F
I*I	I	I-F	F
F/F	F	I-I	I
F/I	F	I**I	I
I/F	F	I++I	I

EXPRESSION - A series of items connected by operators, where an item is a label or a number.

NUMBER - A constant value, positive or negative, may be represented by an octal or decimal constant as described below.

1. An octal constant consists of one or more base 8 digits (0 thru 7).
2. A decimal constant consists of one or more base 10 digits (0 thru 9) followed by the letter D.

These constants may be preceded by a plus sign if positive and must be preceded by a minus sign if negative. A decimal point appearing within or at the beginning or end of the constant identifies the constant as a floating point value. If the decimal point is omitted, it identifies the constant as an integer.

Examples: +77 (positive octal integer)
88.1D (positive floating point decimal number)
-.64 (negative floating point octal number)

To avoid writing many zeros, it is sometimes convenient to express a very large or very small number as a coefficient multiplied by an exponent. Both the coefficient and the exponent must have the same base. If the number is decimal, it must be followed immediately by the D descriptor.

Examples: $.00023_8 = .23_8 * 8^{-3}$ = .23E-3

$1800000_{10} = 18_{10} * 10^5$ = 18E5D

$15000_{10} = 1.5_{10} * 10^4$ = 1.5E4D

$7300_8 = 7.3_8 * 8^3$ = 7.3E3

The constant 25E8 is illegal since 8 is a decimal integer and is not followed by a D.

Examples: 2500000000_8 = 25E10

2500000000_{10} = 25E8D

LITERAL - Should the entire operand field be enclosed by parentheses, then the computed value within the parentheses will be defined as a literal. The assembler will generate a word of data containing the expression value; the value assigned to the literal is the address of this data word. All literals will be located following symbolically generated data (from DATA cards) and duplicates will be eliminated.

REFLEXIVE ADDRESSING - The symbol $ has a special meaning to the assembler. Under some circumstances it may be necessary to code an instruction whose meaning is "load the contents of the following memory location in the accumulator." One method of accomplishing this would be the definition of a label on the following line and a reference to that label as operand of the load instruction. To obviate the necessity for placing a label on every line to be thus referenced, the symbol $ may be employed in the following manner: for every word generated, whether data or instructions, the symbol $ has a value equal to the address of that word while the assembler is generating the word. For example a line specifying LOAD $+1 would result in the generation of the instruction to load the following word. The act of making the operand relative to the instruction being generated is known as reflexive addressing.

UNDEFINED LABEL - A label may be referenced (i.e., used in an operand expression) which is not defined within the program being assembled, but which is defined in another program to be loaded with this one. Such a label is called undefined and its occurrence is indicated by the assembler, but is not necessarily an error.

EXTERNALLY DEFINED LABEL - Normally labels are defined only within the program currently being assembled. However, when using separately assembled subprograms, it is necessary to make the definition of a label available to other programs. This is accomplished by appending an asterisk to the label when it is defined (i.e., when it appears in the label field of a symbolic line of coding).

Before presenting illustrations of the foregoing definitions and explanations, it is desirable to list the mnemonic operations and pseudo-operations defined by the set of procedures which make up the WADSP assembler. The distinction between operations (ops) and pseudo-operations (pseudo-ops) is that ops refer to machine instructions on a one-for-one basis, whereas pseudo-ops direct the assembler to perform certain processing on the data contained in the operand field. For each symbolic line containing an op mnemonic in the operation field, one instruction word is generated by the assembler. For each symbolic line containing a pseudo-op in the operation field, any number of words (including zero) of any type (instruction or data) may be generated, depending upon the pseudo-op employed.

The mnemonics for machine instructions recognized by the WADSP assembler are listed in table 3, with the corresponding names.

The pseudo-op mnemonics, with their definitions, are presented in table 4.

The following examples will serve to illustrate and clarify the previous exposition.

EXAMPLE 1

```
XLAB      LD      Y      LOAD  Y
```

Explanation - The line label is XLAB, the operand is Y, and the comment is LOAD Y. One machine instruction will be generated, with the operation code for a load instruction, and an address field containing the value of the label Y.

EXAMPLE 2

```
          SI      O.
```

Explanation - No label is present. The period followed by blank ends the line. An instruction will be generated to store the IX in location O.

EXAMPLE 3

```
A         J       $+2D
```

Explanation - Reflexive addressing is being used. During assembly of this instruction, the symbol $ has the value A, the location of this instruction. The coding generated is the same as that which would be generated if the operand were A + 2 .

EXAMPLE 4

```
P         EQUALS          4095D
          LD              P
```

Explanation - The label P is assigned the value 4095. No storage is allocated. The second card would place the contents of location 4095 in the Accumulator.

EXAMPLE 5

```
.  THIS  LINE  IS  A  COMMENT
```

Explanation - The period followed by blank begins the comment field. Thus the entire card contains only comments.

EXAMPLE 6

```
A3*       DATA    3.0D*/-2D
          DATA    -036,1.5E-1
```

Explanation - The label A3 on card 1 will be externally defined because of the asterisk appended and its definition will thus be available to other programs to be loaded with the current program. Card 1 will cause a fractional 18-bit data word containing $3/2^2=3/4$ to be generated (octal 300000). Card 2 will cause an integer two's-complement value to be generated (octal 777742) and a fractional value to be generated (octal 300000).

EXAMPLE 7

```
+(A**(B*/4))
```

Explanation - Since no operation is present, a data word will be generated containing the value of the expression in the operand field. Because there are parentheses bracing the expression, the value of the expression will be treated as a literal and stored as such. The memory location represented by this card will contain the address of the literal.

EXAMPLE 8

```
        JI      OUT
OUT     DATA    ERTN
        ...
ERTN*   SBD     1
```

Explanation - The location OUT contains the address of the SBD instruction. The * on the ERTN label in conjunction with the JI allows jumping from a routine in one block to a routine in any other block.

TABLE 3. WADSP ASSEMBLER OPERATION MNEMONICS

Mnemonic	Octal Code	Instruction Name
A	40	Add
AX	41	Add Indexed
AI	46	Add to Index
AIX	47	Add to Index Indexed
AND	56	And
ANDX	57	And Indexed
CM	42	Compare Magnitude
CMX	43	Compare Magnitude Indexed
D	72	Divide
DX	73	Divide Indexed
DLL	022	Double Left Logical Shift
DLLX	032	Double Left Logical Shift Indexed
DLN	04	Double Length Normalize
DLNX	05	Double Length Normalize Indexed
DRA	021	Double Right Algebraic Shift
DRAX	031	Double Right Algebraic Shift Indexed
DRC	023	Double Right Circular Shift
DRCX	033	Double Right Circular Shift Indexed
DRL	020	Double Right Logical Shift
DRLX	030	Double Right Logical Shift Indexed
H	00	Halt
HX	01	Halt Indexed
I	36	Input
IX	37	Input Indexed
J	14	Jump
JX	15	Jump Indexed
JI	74	Jump Indirect
JIX	75	Jump Indirect Indexed
JS	06	Subroutine Jump
JSX	07	Subroutine Jump Indexed
LA	52	Load Absolute
LAX	53	Load Absolute Indexed
LB	200002	Load AC with BR
LC	200001	Load AC with Carry
LD	50	Load AC
LDX	51	Load AC Indexed
LI	64	Load Index
LIX	65	Load Index Indexed
LO	200004	Load AC with Overflow
LQ	62	Load MQ
LQX	63	Load MQ Indexed
M	70	Multiply
MX	71	Multiply Indexed
N	54	Nand
NX	55	Nand Indexed
O	76	Output
OX	77	Output Indexed

Mnemonic	Octal Code	Instruction Name
OR	60	Or
ORX	61	Or Indexed
RT	20	Register Transfer
RTX	21	Register Transfer Indexed
S	44	Subtract
SX	45	Subtract Indexed
SB	200020	Set Block
SBD	200100	Set Block Direct
SC	200010	Set Carry from AC
SE	16	Select
SEX	17	Select Indexed
SH	02	Shift
SHX	03	Shift Indexed
SI	24	Store Index
SIX	25	Store Index Indexed
SK	10	Skip
SKX	11	Skip Indexed
SLL	026	Single Left Logical Shift
SLLX	036	Single Left Logical Shift Indexed
SO	200040	Set Overflow from AC
SQ	22	Store MQ
SQX	23	Store MQ Indexed
SRA	025	Single Right Algebraic Shift
SRAX	035	Single Right Algebraic Shift Indexed
SRC	027	Single Right Circular Shift
SRCX	037	Single Right Circular Shift Indexed
SRL	024	Single Right Logical Shift
SRLX	034	Single Right Logical Shift Indexed
ST	26	Store AC
STX	27	Store AC Indexed
TC	100020	Test Carry
TE	100100	Test AC Even
TGZ	100200	Test AC Greater than Zero
TGEZ	100600	Test AC Greater or Equal Zero
TIR	104000	Test Input Ready
TIZ	100010	Test Index Zero
TLZ	101000	Test AC Less than Zero
TLEZ	101400	Test AC Less or Equal Zero
TNZ	101200	Test AC Nonzero
TO	102000	Test AC Odd
TOV	100040	Test Overflow
TSS	100001/2/4	Test Sense Switch
TEZ	100400	Test AC Equal to Zero

TABLE 4. WADSP PSEUDO-OPERATION MNEMONICS

Mnemonic	Definition
END	Indicates to the assembler the end of symbolic input. It is physically the last card of each assembly, and neither label nor operand may be used with it.
EQUALS	For the duration of the assembly, the label (which is required) has the value of the operand in all expression evaluations.
SET	This operation is functionally the same as EQUALS except that the same label name may appear on more than one SET instruction without being multiply defined. The label value will be redefined with each SET.
SAVE	The number of locations specified by the operand value is reserved.
PROTCT	The memory locations following, until the occurrence of a UNPRCT pseudo-op, are protected by the setting of bit 19, the memory protect bit.
UNPRCT	The memory locations following, until the occurrence of a PROTCT pseudo-op, are unprotected and bit 19 is set to zero.
BLOCK	The operand value must have a value between 0 and 7 inclusive. The three assembler address (relocation) counters are set to this operand value times 10000 octal.
DATA	The operand field contains one or more expressions separated by commas. One memory location will be reserved under location counter 2 for each expression. If the expression is a literal or a single label name, the memory location will contain a 15 bit address of the value. The assembler output is relocatable binary code and is under the control of 3 separate location counters. Instructions are allocated under control of location counter 1. Data from DATA cards is allocated under location counter 2. Literals are allocated under location counter 2 after all DATA (duplicates are eliminated). SAVE instructions are allocated under location counter 3.
SAVD	The same as DATA except that location counter 3 is used.
SAVC	The same as DATA except that location counter 4 is used.
BLKADR	The operand field contains an expression and one memory location will be reserved under location counter 2. The final memory location loaded will contain a 12 bit address of the value.

EXAMPLE 9

```
J       LAB
SAVE    6
LD      (5)
```

Explanation - After the jump instruction generated by card 1, 6 locations (initialized to zero) will be reserved under location counter 3 before generating the load instruction specified by card 3, as a result of the SAVE pseudo-op on card 2. Note that the operand in card 3 is a literal. The assembler will generate a data word containing the integer value 5, place it with other literals at the end of the program, and insert the address of this data word in the address field of the load instruction generated by card 3.

ERROR FLAGS

R - indicates that the operand expression has used a symbol name (representing a memory address) in a way in which the resulting value (after loading) will be incorrect. Thus it is a Relocation error.

(- indicates that the operand expression is missing at least one left parenthesis.

) - indicates that the operand expression is missing at least one right parenthesis.

U - indicates that the operand expression has used a symbol name which has not been defined in this program.

S - a store-type instruction has referenced a memory location under location counter 2 (data).

T - expression value too large for its intended field size.

M - a symbol has appeared more than once in the label field (exception: when symbol is the label on a SET pseudo-op instruction)

L - an error in the label field or missing label

I - an illegal instruction code has been used

O - an error has been found in the operand field

J - a jump-type instruction has referenced a memory location under location counter 2 (data) or 3 (save).

SYSTEM CONTROL CARDS

All control cards must have an = punched in column 1. The alphabetic character punched in column 2 determines what function is to be performed. The allowable characters for column 2 are: A,B,C,D,E,L,P,S and U; their functions are described below.

=AnmNAME

This card causes the executive program to call up the Assembler to assemble the next assembly language program through the END card. The name (NAME) of the program must start in column 5 and only the first twelve characters are retained. No blanks may appear in the program name.

The character n in column 3 is an option which can cause a purge of the source input prior to execution of the source by the assembler. This purging causes the 1108 oriented source to be converted to CMS-2 oriented source. For example: FC,OC,IC, and ADDR are changed to DATA; a D is added to the end of all decimal constants, etc. If n is a blank or a zero, then the purge is not performed. If n is a number greater than zero, then the purge is performed.

The character m determines the mode of source input to the assembler. If the character is a T the input for this assembly will be read from magnetic tape. The tape is searched in a forward direction only for the program whose name (NAME) appears on the control card. The assembly control cards must be in the same sequence as the programs appear on the magnetic tape. If the character m is a D, then the source input to the assembler will be read from the user's PCF. This D select only applies to the 1108 system. It is assumed that the source input has been placed on the PCF by a CUR operation. NAME is the name of the element on the PCF. If m is a C (or any character other than T or D) then the input to the assembler will be read from the card reader.

The assembled binary and symbol names with their addresses are accumulated on an output file.

=Bn

This control card designates the number of banks of memory which are to be loaded. The value of n must be between one and eight inclusive. If this control card is not used or if the value of n is not in the limit specified, then the number of banks is assumed to be four. This card must appear prior to the load control card.

=CnnNAME

This control card causes the executive program to call up the CMS-2 compiler. Only one SYSTEM may be compiled under this control card. The fields on the =C card are identical in meaning with these on the =A card except that here n must equal 0. Following compilation the assembler is automatically called. Figure 4 illustrates a typical control card setup for a compilation, load, and punch.

=Ddate

This control card allows a date to be read into the executive program. The date is assumed to be the twelve alpha-numeric characters beginning in column 3. This date will print on the header line to the loader output listing.

=E

This control card causes the executive program to turn on various error check debugging flags. With these flags set, various lines of intermediate debugging print will be output. In general, this card need not and should not be used.

=Ln$
NAME1,NAME2,NAME3
NAME4

This control card causes the executive program to call up the Loader. The character n must be a blank, one, two, or three punched in column 3. This control is used to print (or not print) the combined noun table, showing the noun name and its absolute address. If the character n is a blank or a zero, the noun table listing is not produced. If the character n is a one, then the noun table is printed in alphanumerical sequence by name. If n is a two, then the noun table is printed in absolute address sequence. A three will print the noun table in absolute address sequence and also alpha-numerical sequence.

The $ indicates selective loading to the Loader. If the control character n is non-blank, then the $ must be punched in column 4. If n is meant to be blank and selective loading is desired, then the $ must be in column 3. The program names listed on the following cards will be loaded. There must be a blank in column 1 of the program name cards and as many cards as needed may be used. However, the number of program names is limited to one hundred. The order in which the specified programs are loaded is the order in which they are assembled, or appear on the updated binary file (see =U control card). Reading of the program name cards continue until a control card is read; therefore, a control card must end the series. An =E control card may be used if none other is applicable.

Loading is performed in the following manner. The memory required for each program in succession to be loaded is summed. The memory required includes instructions, Data, and Save type storage (each of which is under a different location counter). As many programs as will fit in the first bank is then loaded. The instructions for all bank 0 are loaded starting at location 00000, then Data for all bank 0 programs and finally all Save locations. The process continues until all program are loaded with all unloaded locations containing zeros.

=Pm,n K
  string of characters

This control card causes the executive program to call up the Binary Paper tape Routine. The use of this control card assumes that the = L control card has preceded. The output will be on a magnetic tape which must then be converted to paper tape via another program.

The octal numbers represented by m and n are the lower and upper limit of core storage to be punched. The value of n must be greater than the value of m. If ,n is not present, then the lower limit is assumed to be zero and the upper limit is the value of m. If neither m nor n appears, then the lower limit of zero is assumed and the upper limit is set to the last location stored by the Loader. All of loaded memory may then be punched by not specifying the limits to be punched.

A label (string of alpha-numeric characters including ()-/) may be punched at the beginning and end of the paper tape. The string of characters (limit of 79) should appear in the card following the =P control card. There must be a blank in column one of this card. The number of characters to appear in the label is specified by the value of K in the control card. There must be one blank separating K from the preceding characters in the control card. If K is not present or has the value zero, then no label will be punched on the paper tape and the "string of characters" card must not be present.

=S

This control card causes the executive program to call up the Simulator. The use of this control card assumes that the =L control card has preceded. The simulator is available only on the 1108 system. The required correction of the simulator file are shown in figure 3.

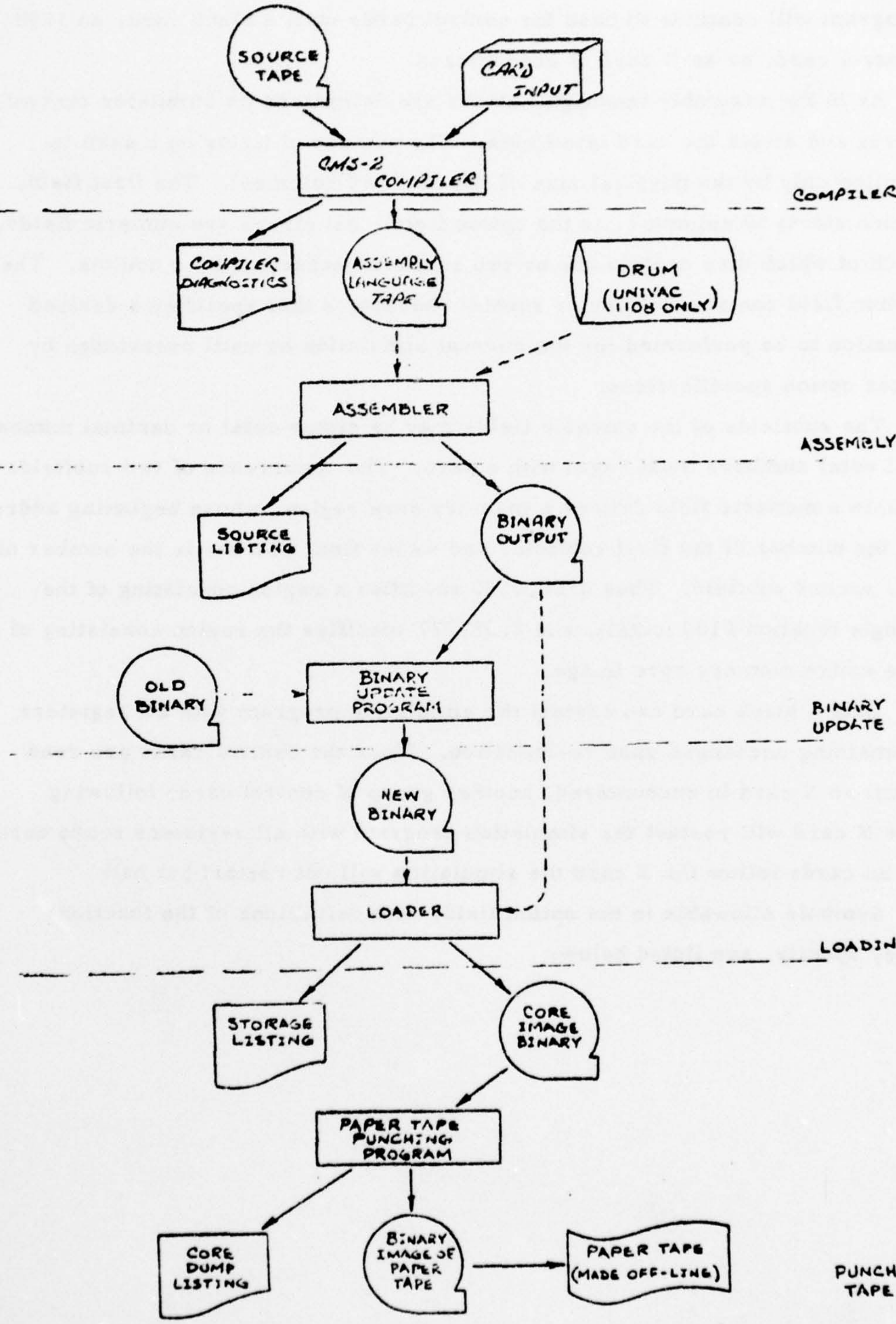

SOURCE TAPE
CARD INPUT
CMS-2 COMPILER
COMPILER
COMPILER DIAGNOSTICS
ASSEMBLY LANGUAGE TAPE
DRUM (UNIVAC 1108 ONLY)
ASSEMBLER
ASSEMBLY
SOURCE LISTING
BINARY OUTPUT
OLD BINARY
BINARY UPDATE PROGRAM
BINARY UPDATE
NEW BINARY
LOADER
LOADING
STORAGE LISTING
CORE IMAGE BINARY
PAPER TAPE PUNCHING PROGRAM
CORE DUMP LISTING
BINARY IMAGE OF PAPER TAPE
PAPER TAPE (MADE OFF-LINE)
PUNCH TAPE

FIGURE 2.

Control cards are used as input data by the simulator. The simulation program will continue to read the control cards until a blank card, an 1108 control card, or an X card is encountered.

As in the assembly language, blanks are delimiters on simulator control cards and divide the card into fields. The number of fields on a card is limited only by the physical size of the card (80 columns). The first field, which starts in column 1, is the option field. All others are numeric fields, each of which may contain one or two subfields separated by a comma. The option field contains letters or special characters that specifies a desired function to be performed for the current simulation or until overridden by later option specifications.

The subfields of the numeric fields may be either octal or decimal numbers. All octal numbers must begin with a zero. The occurrence of two subfields within a numeric field defines a memory core region, whose beginning address is the number of the first subfield, and whose final address is the number of the second subfield. Thus 0100,0100 specifies a region consisting of the single location 0100 (octal), and 0,037777 specifies the region consisting of the entire memory core image.

Only a blank card can restart the simulation program with all registers remaining unchanged upon re-initiation. Since the control cards are read until an X card in encountered, another group of control cards following the X card will restart the simulation program with all registers set to zero. If no cards follow the X card the simulation will not restart but halt.

Symbols allowable in the option field, with definitions of the functions they specify, are listed below.

SIMULATOR OPTIONS

Symbol

C **Numeric field** n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Option Definition - During simulation, when an instruction is executed in any of the regions specified by the numeric field, various statistics for the opcode are compiled. When simulation is discontinued, a count of the following is given for each opcode:

1. number of instructions in storage for all memory
2. number of instructions executed within the specified region
3. time required for (2)
4. percent of the total time required for (2)

Purpose - To provide a statistical analysis of each opcode used in the program for the regions specified.

Example of control card

```
column  1                                                  80
        C        0,0454
```

Example of Output

Op-Code	Avg. Time	Storage Count	Execution Count	Total Time For Operation	% Of Time For Operation
H	1.60	1	1	1.60	.23
HX	2.60	0	0	.00	.00
SH	1.60	12	12	19.20	2.79
SHX	2.60	10	9	23.40	3.40
DLN	3.40	1	1	3.40	.49
DLNX	4.40	0	0	.00	.00
JS	2.20	1	1	2.20	.32
JSX	3.20	1	1	3.20	.46

Op-Code	Avg. Time	Storage Count	Execution Count	Total Time For Operation	% Of Time For Operation
SK	1.20	28	28	33.60	4.88
SKX	2.20	0	0	.00	.00
J	2.20	1	1	2.20	.32
JX	3.20	1	1	3.20	.46
SE	.00	1	1	.00	.00
SEX	1.00	0	0	.00	.00
RT	1.60	5	4	6.40	.93
RTX	2.60	0	0	.00	.00
SQ	3.40	2	2	6.80	.99
SQX	4.40	0	0	.00	.00
SI	3.40	1	1	3.40	.49
SIX	4.40	0	0	.00	.00
ST	3.40	2	1	3.40	.49
STX	4.40	0	0	.00	.00
I	.00	1	1	.00	.00
IX	1.00	0	0	.00	.00
A	3.20	21	6	19.20	2.79
AX	4.20	1	1	4.20	.61
CM	3.60	0	0	3.60	.52
CMX	4.60	0	0	.00	.00
S	3.20	1	1	3.20	.46
SX	4.20	1	1	4.20	.61
AI	3.00	0	0	.00	.00
AIX	4.00	0	0	.00	.00
LD	3.20	36	36	115.20	16.72
LDX	4.20	2	2	8.40	1.22
LA	3.60	2	2	7.20	1.04
LAX	4.60	0	0	.00	.00

Op-Code	Avg. Time	Storage Count	Execution Count	Total Time For Operation	% Of Time For Operation
N	3.40	1	1	3.40	.49
NX	4.40	0	0	.00	.00
AND	3.40	1	1	3.40	.49
ANDX	4.40	0	0	.00	.00
OR	3.40	2	2	6.80	.99
ORX	4.40	0	0	.00	.00
LQ	3.20	8	8	25.60	3.72
LQX	4.20	0	0	.00	.00
LI	3.00	10	9	27.00	3.92
LIX	4.00	1	1	4.00	.58
M	23.20	3	3	69.60	10.10
MX	24.20	3	3	72.60	10.54
D	34.40	1	1	34.40	4.99
DX	35.40	3	3	106.20	15.41
JI	3.00	1	1	3.00	.44
JIX	4.00	1	1	4.00	.58
O	.00	1	1	.00	.00
OX	1.00	0	0	.00	.00
INDEXING	1.00	24	23	23.00	3.34
MISC. TIME				28.80	4.18

Symbol

D	Numeric Field n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Option Definition - When simulation is discontinued, an octal dump of memory is printed for all of the regions specified by the numeric field.

Purpose - This option is used to see what data has been stored in the areas specified by the numeric field when the simulated program is to long to trace.

Example of Control Card

column 1 ... 80

```
D     037,0116     0217,0247
```

Example of Output

```
00037 640263 450263 440261 500264 700261 500264 710263 500304
00047 710263 5000305 710263 500306 700263 700265 500260 620265
00057 021021 730263 500261 620265 021021 730263 500305 620265
00067 021021 730263 220274 500274 620265 021021 720263 500260
00077 020003 030002 022006 032002 021003 031002 023006 033002
00107 500260 024003 034002 026006 036002 025003 035002 027006

00217 500263 102000 400263 104000 160001 500260 200001 200004
00227 200010 200040 360001 500260 420261 400263 520262 520260
00237 540262 560262 600265 600260 760001 640265 140250 400263
00247 260274
```

Symbol

E Numeric Field b where b may be octal or decimal; but only a single number may appear in the numeric field.

Option Definition - This option defines the maximum numbers of instructions to be executed before discontinuing simulation. This number is set to 100,000 (decimal) if no E option is selected.

Purpose - To prevent a large number of instructions from being executed when the program is caught in a loop.

Example of Control Card

```
column  1                                                    80
       /E    500                                               )
```

Example of Output - The following message is printed when the maximum number of instructions executed has been exceeded:

EXECUTION LIMIT OF 500 ON INSTRUCTIONS EXCEEDED

F Numeric Field n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Option Definition - Whenever a jump-type instruction (J, JI, or JS) is executed within the regions specified by the numeric field, a trace message will be printed indicating the transfer of control.

Purpose - When trace is turned off, this option provides a trace of the flow through the program's various routines and subroutines.

Example of Control Card

```
column  1                                                    80
       /F    010242, 021265                                    )
```

Example of Output - The following message is printed when a jump instruction is executed within the region specified by the numeric field:

FLOW: JUMP (JS) FROM 010242 TO 0403

Symbol

G **Numeric Field** - No numeric field may appear on the card other than a comment.

Option Definition - When a halt opcode is encountered, it is executed as a halt; otherwise, it is executed as a no-op and simulation will continue with the next location in memory being executed as an instruction.

Purpose - This option provides a method for halting the simulation of a program.

Example of Control Card

column 1 ... 80

G

Example of Output

IC	OP-CODE	IRS	ACC	MQ	MOR	EAR	IDX	BR	CRY	OVF	IC-NEXT	TIME
00256	LI	640263	777777	000001	000001	00263	00001	0	0	0	00257	728
00257	H	000000	777777	000001	000001	00000	00001	0	0	0	00260	729

Number of instructions executed = 162

Running time of 729 microsecs Execution time of 2 secs

Halt executed as a no-op:

IC	OP-CODE	IRS	ACC	MQ	MOR	EAR	IDX	BR	CRY	OVF	IC-NEXT	TIME
00257	H	000000	777777	000001	000001	00000	00001	0	0	0	00260	1446
00260	SIX	252525	777777	000001	000001	02526	00001	0	0	0	00261	1450
00261	LA	525252	000000	000001	000000	05252	00001	0	0	0	00262	1454

H **Numeric Field** - n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Option Definition - Whenever control is transferred within one of these regions, simulation will be discontinued regardless of the instruction fetched.

Purpose - This option protects areas of memory and does not allow instructions to be executed.

Example of Control Card

```
column  1                                                    80
       G    0,07777
```

Example of Output

STOP INSTRUCTION EXECUTED; LOCATION 20, TIME 500 MICROSECS

I   Numeric Field - b where b may be octal or decimal; but only a single number may appear in the numeric field.

Option Definition - The numeric field represents the number of micro-seconds to elapse between generation of interrupts. If this option is not selected, no interrupts will be generated.

Purpose - This option provides a method to allow interrupt simulation for operational programs which have interrupts.

Symbol

Example of Control Card

```
column  1                                                    80
       I    5000
```

Example of Output

INTERRUPT

J, K   Numeric Field n, m i, j where n and i are beginning addresses and
L, M   m and j are final addresses of memory regions.

Option Definition - When control is transferred within the area defined by one of these letters, the entire area specified will be dumped in octal form. If the numeric field defines a data area, the data area will be dumped whever any location in that area is used by an instruction in the program.

Purpose - This option can be used as a debug aid to determine errors made in data storing or data calculations.

Example of Control Card

```
column  1                                                    80
       M    0160, 0170
```

Example of Output

IC	OP-CODE	IRS	ACC	MQ	MOR	EAR	IDX	BR	CRY	OVF	IC-NEXT	TIME
00170	TGEZ	100600	000001	000001	000001	00600	00000	0	0	0	00172	606

```
***DUMP M**
00160 500263 100400 500265 100400 400263 500272 500272 100600 500263
00170 100500
```

00172	LD	500265	000000	000001	000000	00265	00000	0	0	0	00173	609
00173	TGEZ	100600	000000	000001	000000	00600	00000	0	0	0	00175	611

Symbol

Symbol

Q Numeric Field n, k where n specifies an address of memory and k specifies a clock and must be one of the numbers 0, 1, 2, or 3.

Option Definition - Whenever the instruction at the specified locations is executed, the difference between the simulation time and the selected clock time will be printed.

Purpose - This option provides a method of timing various segments of a program when used along with the R option.

Example of Control Card

```
column  1                                                    80
       Q     017777, 1
```

Example of Output

ELAPSED TIME = 1629 MICROSECS CLOCK NO. 1

R Numeric Field n, k where n specifies an address of memory and k specifies a clock and must be one of the numbers 0, 1, 2, or 3.

Option Definition - Whenever the instruction at one of the specified locations is executed, the selected clock will be set to the current value of the simulation time and a message will be printed to indicate that this has occurred.

Purpose - This option provides a method of timing various segments of a program when used along with the Q option.

Example of Control Card

column 1 80

```
R   016740, 1
```

Example of Output

CLOCK NO. 1 RESET TO 5010 MICROSECS

S Numeric Field n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Symbol ∩

Option Definition - If an instruction in the simulated program attempts to store in any of the regions specified by the numeric field, the store will be inhibited and a message will be printed to indicate the occurrence.

Purpose - This option prohibits storing into a protected area of memory. Thus both constants of the program and instructions can be protected from change while the program is being executed.

Example of Control Card

column 1 80

```
S   0,014764   020000, 025710
```

Example of Output

**DATA STORE ATTEMPTED INTO RESTRICTED MEMORY;
LOCATION 012751**

T Numeric Field n, m i, j . . . where n and i are beginning addresses and m and j are final addresses of memory regions.

Option Definition - Whenever an instruction is executed in any of these regions, a single line will be printed containing a dump of the contents of all programmable registers in octal and also in fractional decimal where applicable. In addition, accumulated simulation time will be printed in microseconds.

When an instruction is executed in any of the unspecified regions, only a trace of the output instructions with the latest select code and time of the select is printed.

Purpose - By turning trace on and off as needed, both computer time and number of pages printed can be minimized.

Example of Control Card

```
column  1                                                     80
        T   0.0242   021574, 022604
```

Example of Output

IC	OP-CODE	IRS	ACC	MQ	MOR	EAR	IDX	BR	CRY	OVF	IC-NEXT	TIME
00000	LD	500260	252525	000000	252525	00260	00000	0	0	0	00001	3
00001	ST	260274	252525	000000	252525	00274	00000	0	0	0	00001	6
00002	LD	500265	000000	000000	000000	00265	00000	0	0	0	00002	9
00003	LD	500274	000000	000000	000000	00274	00000	0	0	0	00003	13
00004	LQ	620260	000000	252525	252525	00260	00000	0	0	0	00005	16

U Numeric Field a b c . . . where a b c . . . are letters representing control options and must be separated by one or more blanks.

Option Definition - This control card must be the first card following an x or blank option control card. The numeric field represents options from the previous group of control cards which are to be saved and used with the present set of control cards.

Purpose - This option eliminates duplication of control cards when the simulated program is re-executed within the same computer run.

Example of Control Card

```
column  1                                                     80
        U     E     G     X     F
```

Example of Output

previous set of control cards:

E	200	· Maximum Instructions
G		· Halt Option
D	037,0117 0217,0247	· Dump
F	0230,0257	· Flow of Jump Instructions
J	040,052	· Dynamic Dump
L	0100,0104	

	M	0160,0170		
	Q	0230,1 0144,2		· Clock Time
	R	0200,1 0,2		· Simulation Clock Time
	S	0,0257 0274,0274		· Protect
Symbol				
	T	0,050 0159,0400		
	X	0		· IC Initial Value

present set of control cards:

U	E	G	X	F	
K		020,026			
T		0,0242			· Trace
					· Re-initiate Processing

beginning trace of program upon re-initiation:

IC	OP-CODE	IRS	ACC	MQ	MOR	EAR	IDX	BR	CRY	OVF	IC-NEXT	TIME
00000	LD	500260	252525	000000	252525	00260	00000	0	0	0	00001	3
00001	ST	260274	252525	000000	252525	00274	00000	0	0	0	00002	6
00002	LD	500265	000000	000000	000000	00265	00000	0	0	0	00003	9
00003	LD	500274	000000	000000	000000	00274	00000	0	0	0	00004	13

X Numeric Field b where b may be octal or decimal; but only a single number may appear in the numeric field.

Option Definition - The numeric field specifies the initial value with which the instruction counter is to be loaded. If no x option is present, the instruction counter is loaded with 2. This option initiates simulation. If more control cards follow the x card the simulation of the program is re-initiated and all registers will be re-initialized, except those saved with the U option control card.

Purpose - This option allows the instruction counter to be set to any value. Thus simulation maybegin at any point in the program.

Example of Control Card

```
column  1                                                            80
       / X  0                                                          \
```

Symbol

blank Numeric Field - No numeric field may appear on the card other than a comment.

Option Definition - This option is used to re-initiate processing after a simulated halt of the program without changing any register contents.

Purpose - This option allows the program to be executed an many times as needed without submitting separate computer runs.

Example of Control Card

```
column  1                                                            80
       /                                                               \
```

continue Numeric Field - Column 1 is blank and the remainder of the card contains the same numeric field as the option being used.

Purpose - This option allows many numeric fields to be listed on several cards without repunching the option in column 1 each time.

Example of Control Card

```
column  1                                                            80
       / S    0,0308    0400,0452        0528,0651                     \
column  2                                                            80
       /     01011,01213        020121,020212                          \
```

comment Numeric Field - On a card contining an option in column 1, a period anywhere else on the card will make everthing after the period a comment. A whole card or cards may be used as comments only if a period is in column one.

Example of Control Cards

column 1

T	0,037777	· Trace of entire program
G		· Halt Option

· Control Cards for Production Tape Simulation Only

APPENDIX A6

REPORT OF THERMAL TESTING ON AIRCRAFT 304 AT EDWARDS AIR FORCE BASE

Table of Contents

Summary

The F4E/HUD aircraft was visited at Edwards AFB in Mojave, California to determine if the Westinghouse equipment was receiving adequate cooling air when installed in the aircraft. The test consisted of measuring the static air pressure at the rear of the computer plenum structure and comparing that figure to data compiled in our laboratories at Aerospace. The air was supplied by a ground cooling cart (type AN/AWA-6) and at the worst case condition of air leaking through an empty unrestricted nose cone, the computer bay received at least 10% more air than it did at our most severe laboratory test at Aerospace.

Analysis

Comprehensive testing was performed at the PQL at Aerospace to determine the air flow characteristics of the F4E/HUD plenum structure and LRU's 27, 28 and 29. The attached curves give the results of these tests in the form of "static pressure at plenum rear vs. air flow thru LRU's 27, 28 and 29." Because the IFF unit is mounted on the same structure, the curves for that unit appear also.

The three computer units were then prepared for temperature versus airflow tests. Thermocouples were placed at critical component locations in all three computers. A list of thermocouple locations and temperatures is attached. The minimum flow obtainable from the blowers during the temperature tests supplied 1.3" static at the rear of the plenum. The steady state temperatures indicate that at this air flow, the components are operating at temperatures far below the maximum reliable temperature limits.

The test at Edwards AFB indicated that the static pressure at the rear of the plenum will be 1.7" at the worst condition (air leakage) thus supplying the computers with at least 10% more air than was supplied during the minimum air flow/temperature test.

See attached sheet for total aircraft and bench tests at Edwards.

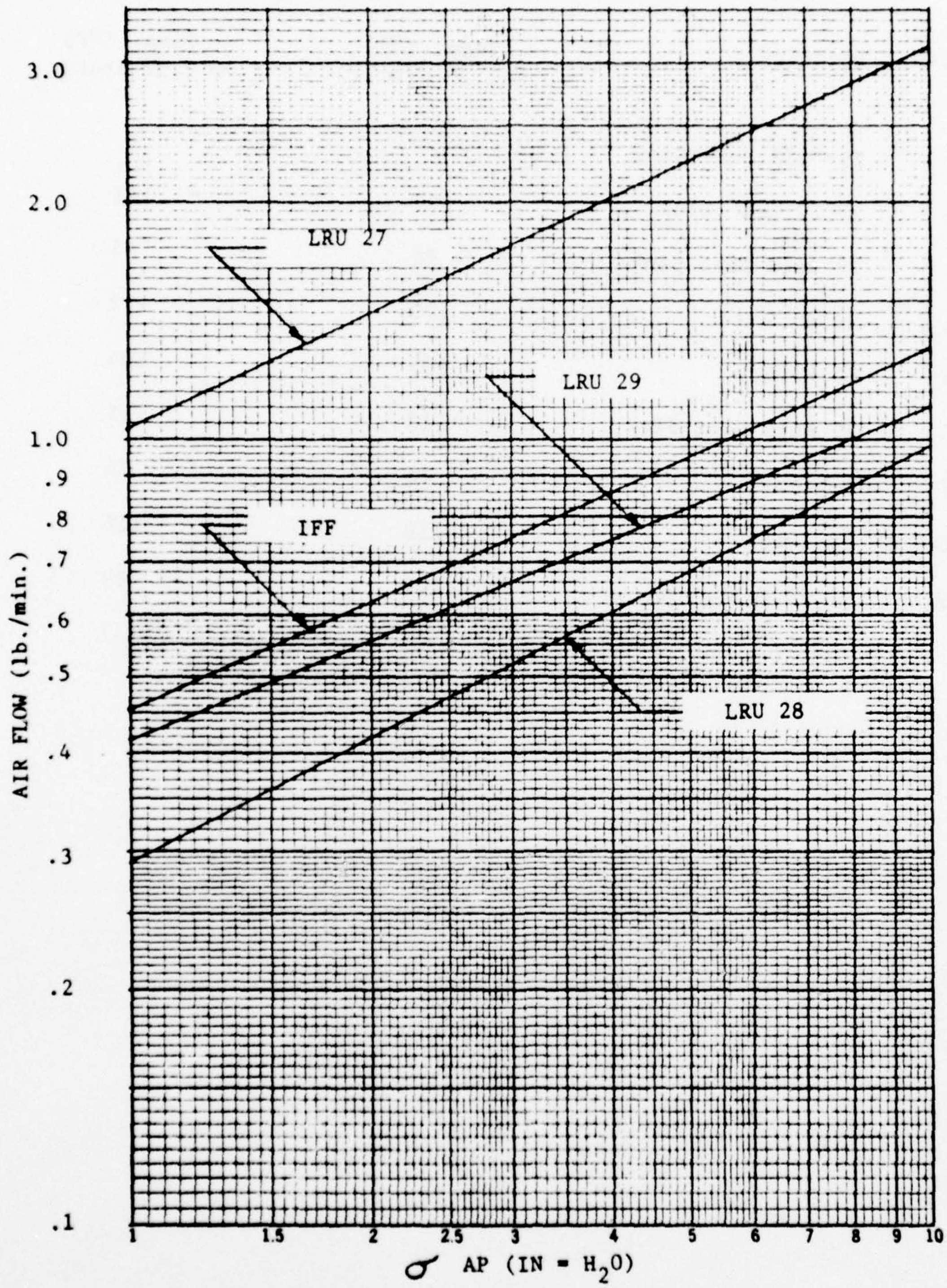
Comments

1) The portion of the test procedure which called for airflow measurements during aircraft engine idle could not be performed because the aircraft was not prepared. Instructions were given to Westinghouse field personnel and to McDonnell personnel to enable them to perform the testing when the aircraft was ready.

The ambient temperature during the laboratory temperature tests was 76°F. The cart supplying air to the F4E is used until the air temperature reaches 85°F. At that time an air conditioning cart with greater capacity is used. This means that at 1.3" pressure it is possible to see temperatures approximately 9°F higher than recorded on attachment.

Thermocouple Locations and Temperatures

T/C#	Location	Temp. (^{o}F) @ 1.3" Static	Temp. (^{o}F) @ 2.5" Static
1	29-5VPS Heat Sink	-	-
2	27 PS Heat Sink	133	126
3	29 A618 Heat Sink	98	96
4	29 A519	120	112
5	27 Memory	105	104
6	29 A612 Heat Sink	115	111
7	Ambient	76	76
8	28 A618	118	116
9	27 PS Heat Sink	102	99



STATIC PRESSURE AT PLENNUM REAR Vs. AIR FLOW THROUGH LRU's 27, 28 and 29

10/29/74
Edwards AFB

Test Description:

I. LRU's 27, 28 and 29 installed in F4E (USAF 80304) computer bay. The orifice holes were taped allowing air to pass only thru the holes as follows:

LRU 27 - 9 holes each 1/4" dia. in plenum

LRU 28 - 6 holes left open (see sketch)

LRU 29 - 2 large holes and 2 small holes open

Air was supplied to the aircraft per the yellow cooling cart (AN/AWA-6).

A. Test with IFF unit not installed and its orifice in plenum open (5/8" dia. hole), and with radar nose package removed and its orifice holes open.

Static pressure at rear structure tap:

$P = 1.7'' \ H_2O$

B. Test with radar package removed but with IFF orifice covered.

$P = 2.1 \text{ in } H_2O$

C. Test with tape restricting nose cone flow:

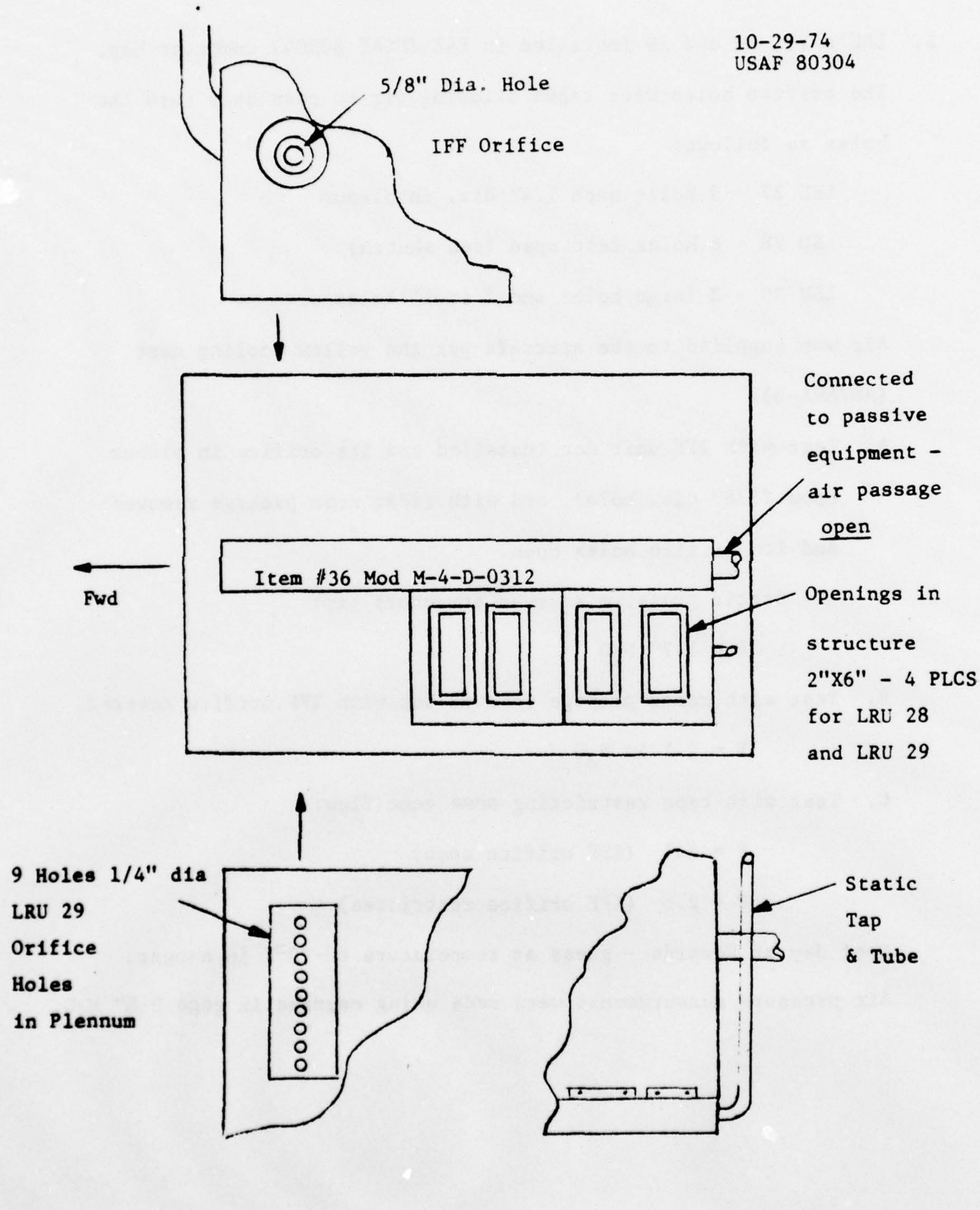
P = 2.1 (IFF orifice open)

P = 2.5 (IFF orifice restricted)

Cool day at Edwards - guess at temperature 68-70°F in hangar.

Air pressure measurements were made using magnahelix gage 0-8" H_2O.

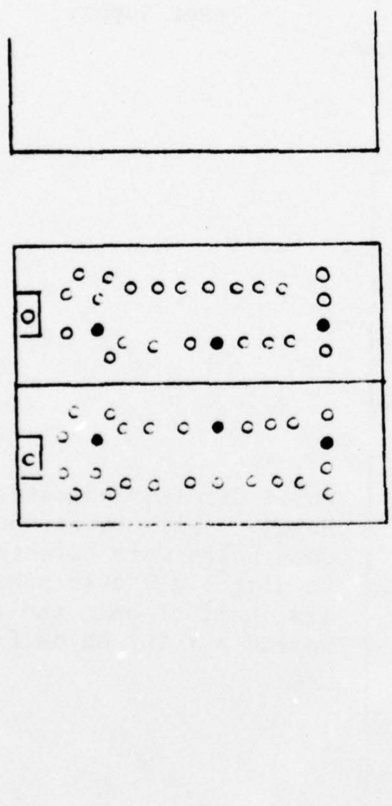
10-29-74
USAF 80304



10-24-74

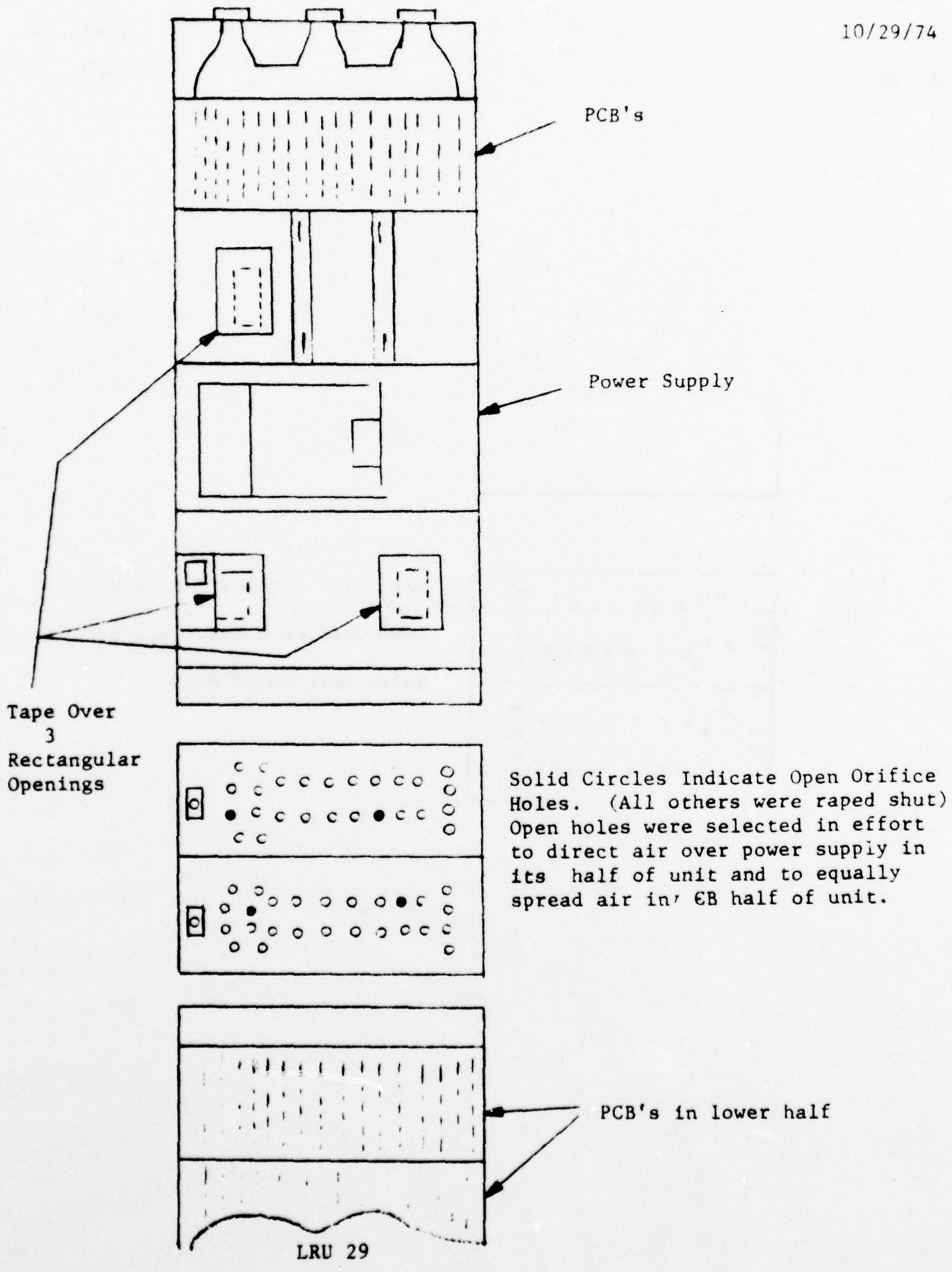
LRU 28

EAFB



Six Solid Circles Indicate Open Orifice Holes. All other Holes were Taped Shut.

10/29/74

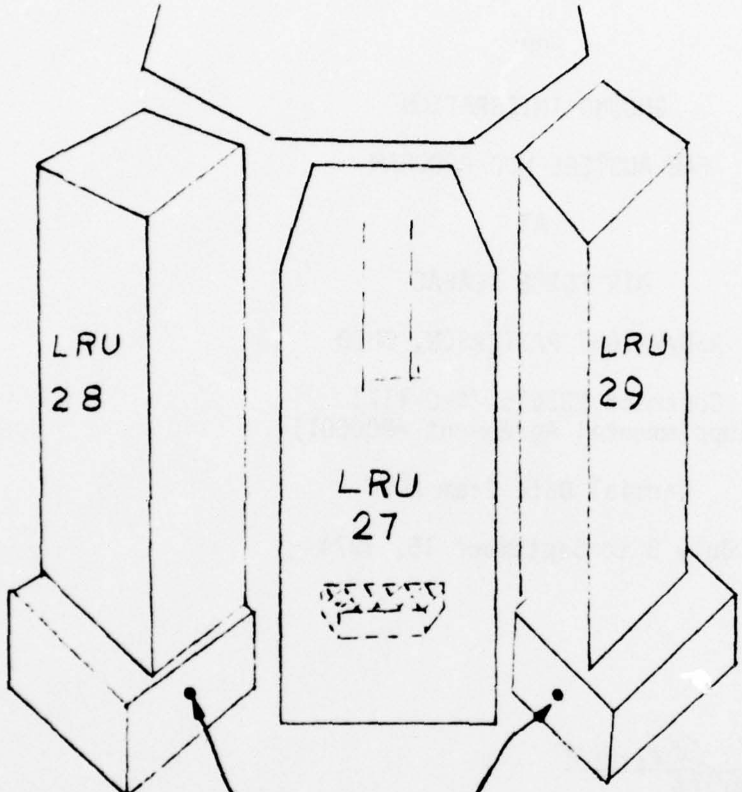


LRU 29

10/20/74

EAFB

Bench Set-up



I. With orifice holes taped closed in LRU 28 and LRU 29 (except 6 holes in 28 and 2 large - 2 small in 29), the units were placed on bench. LRU 27 has no orifice plates and is wide open. Tape is placed over lower air duct under LRU 27, but nothing is used to restrict the air flowing through the large slot in top back of LRU 27.

Blower is turned on and static is measured in plennum under 28 and 29. $\Delta P = 1.5'' \; H_2O$.

APPENDIX A7

TEST PLAN

FOR

GROUND INTEGRATION

F4E AUSTERE HUD PROGRAM

AT

AIR FORCE SEAFAC

ASD/WRIGHT PATTERSON, OHIO

Contract F33615-74-C-1173
(Supplemental Agreement #P00001)

Partial Data Item A006

July 8 to September 15, 1974

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Program Manager, F4E Austere HUD

July 8, 1974

1. TEST PLAN FOR F4E AUSTERE HUD PROGRAM

OBJECTIVE

To use SEAFAC facilities and resources on a minimal interference to other program basis to perform ground integration of Austere HUD program in order to save overall program costs and time. The test/simulation/ground integration will verify and validate the HUD/computer performance under static and dynamic functional conditions such as to simulate actual flight profiles. Also the Mod II kit aircraft wiring and interconnects to APQ-120 Radar will be verified.

ADVANTAGE

By using the Air Force general purpose system integration avionic facilities, special facilities to aid the aircraft systems integration for this specific program need not be developed at additional program costs. In addition, the SEAFAC software facilities for the generation of low cost on-board computer programs will be utilized to show that standard Air Force software techniques are applicable. In this way, Air Force software maintenance will be possible.

REQUIRED FACILITIES/DELIVERABLE ITEMS/INTEGRATION PRINCIPLES

AIR FORCE FACILITIES

(a) SEAFAC hardware facilities on a part time basis.

(b) SEAFAC dynamic aircraft simulation software.

(c) SEAFAC support software facilities.

(d) SEAFAC personnel on a part time basis.

(e) SEAFAC computer maintenance bench.

(f) SEAFAC test equipment on a part time basis.

(g) Vendor, Austere HUD Program vendors support.

DELIVERABLE ITEMS TO SEAFAC

(a) Austere HUD (TI).

(b) Westinghouse F4E modified AN/AYK-8 computer, Westinghouse.

(c) One (1) set of aircraft cabling, Westinghouse.

(d) One (1) addition to SEAFAC simulator for angle rate and acceleration changes. Westinghouse.

(e) One (1) AN/AYK-8 dynamic simulator computer, Westinghouse.

(f) One (1) test routines for HUD/computer integration. Westinghouse.

(g) One (1) aircraft canned operational program for dynamic operation testing. Honeywell and Westinghouse

(h) Dynamic simulator program AF/ASD SEAFAC.

APPROACH

(a) Description of present SEAFAC. (See P.M.P.)

(b) Modification to present SEAFAC for Austere HUD program. (See Figures 1 and 2)

(c) Detailed steps for integration.

- Initial sight preparation - power/space/facilities at SEAFAC.
- Aircraft F4E computer is placed on SEAFAC-57G maintenance bench to verify computer and I/O diagnostics. (Alternate hook up is to be considered if Air Force maintenance bench is not available.

- Aircraft F4E computer is now connected together with F4E aircraft partial cables to permit operation of F4E computer with SEAFAC console and diagnostics are run.
- Austere HUD initial diagnostic program is now read into F4E aircraft computer and signals for HUD serial bus are observed at end of serial HUD lines during which resistors are used for termination. Observation of signals by scopes is made.
- TI introduces HUD and TI manual test set and repeats HUD-serial link command interface test.
- Substitute computer for test set and repeat HUD/test serial link command patterns. Compare pattern to TI etched glass glass mask overlay on TV tube.
- Begin orderly execution of tests to determine boresight/ pattern data generation tests.
  - Computer drives X = 0, Y = 0 spot.
  - Computer gives minimum circle command about 0,0 position.
  - Successively, the circle is increased until maximum circle is commanded.
  - Next, all characters in the table are commanded about the 0,0 position.
  - Next, line segments in the horizontal only plane to the right only are commanded.
  - Next, line segments to the vertical only are commanded in successive line length values.

- Next 30°, 35°, 60°, 75°, and 85° line projections are commanded.
- Repeat in vertical gradient (9 to 10 o'clock).

• Repeat previous tests by offsetting pattern approximately (+45°, +45°), (-45°, +45°), (-45°, -45°) and (+45°, -45°). Length of diagonal variable.

• Perform various intensity and persistence tests.

• Confirm switch setting and values for master modes.

• Perform preliminary acceptance tests per Capt. Koger's requirements.

• Perform the airborne HUD test pattern.

SEAFAC Test Setup

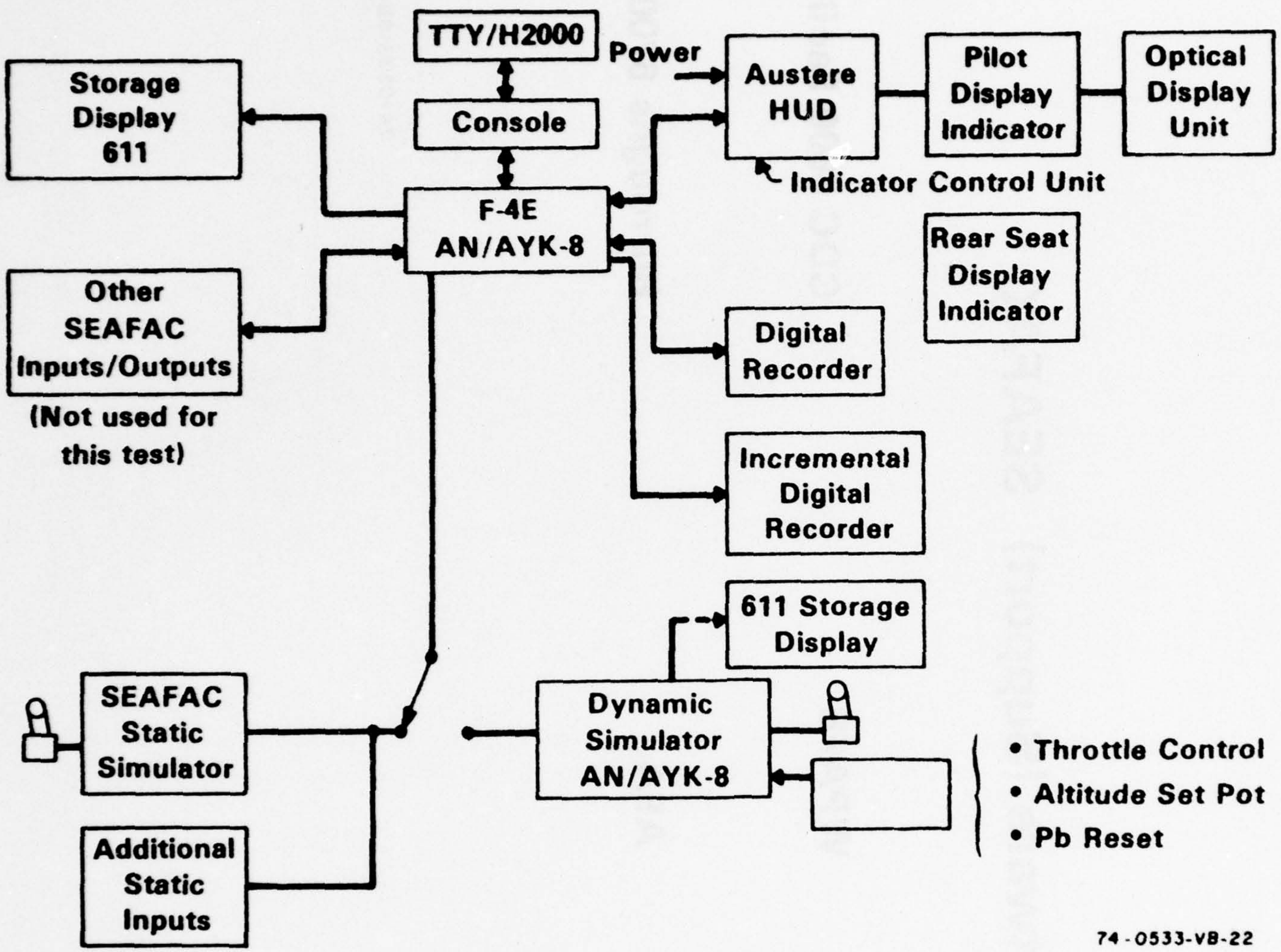


Figure 1

Software (Support) SEAFAC

WPAFB	CDC 6600 Facility
AFA	Burroughs 6700

74-0533-BB-24

Figure 2

These tests should take approximately four weeks. The first week is used for initial setup. (See figure 5.)

The HUD is then shipped to GE for installation of optics. Approximately three weeks will be required here. (See figure 5.)

During this period, the APQ-120 Radar checks will be made to verify the aircraft cabling of APQ-120 to AN/AYK-8.

The detailed procedure is given in Attachment #1.

The static simulator inputs will be verified. This is done by connecting aircraft cabling to toggle switches and then to SEAFAC simulator as follows:

(list of signals in proper sequence of test to be supplied)

The dynamic simulator inputs will also be verified in a similar manner by a test program supplied by Westinghouse.

- A canned dynamic HUD test will be applied upon return of HUD.
- A simple operational program from Honeywell will then be put on the AN/AYK-8 F4E HUD system and test will commence by using static simulator inputs.
- Dynamic inputs will then be applied in place of static inputs in a sequence which will present proper display of aircraft and target on the 611 storage tube.
  (Detailed plan to be provided.)
- Figures 3 and 4 show the approach for switching between static and dynamic simulation.

Ground Simulation

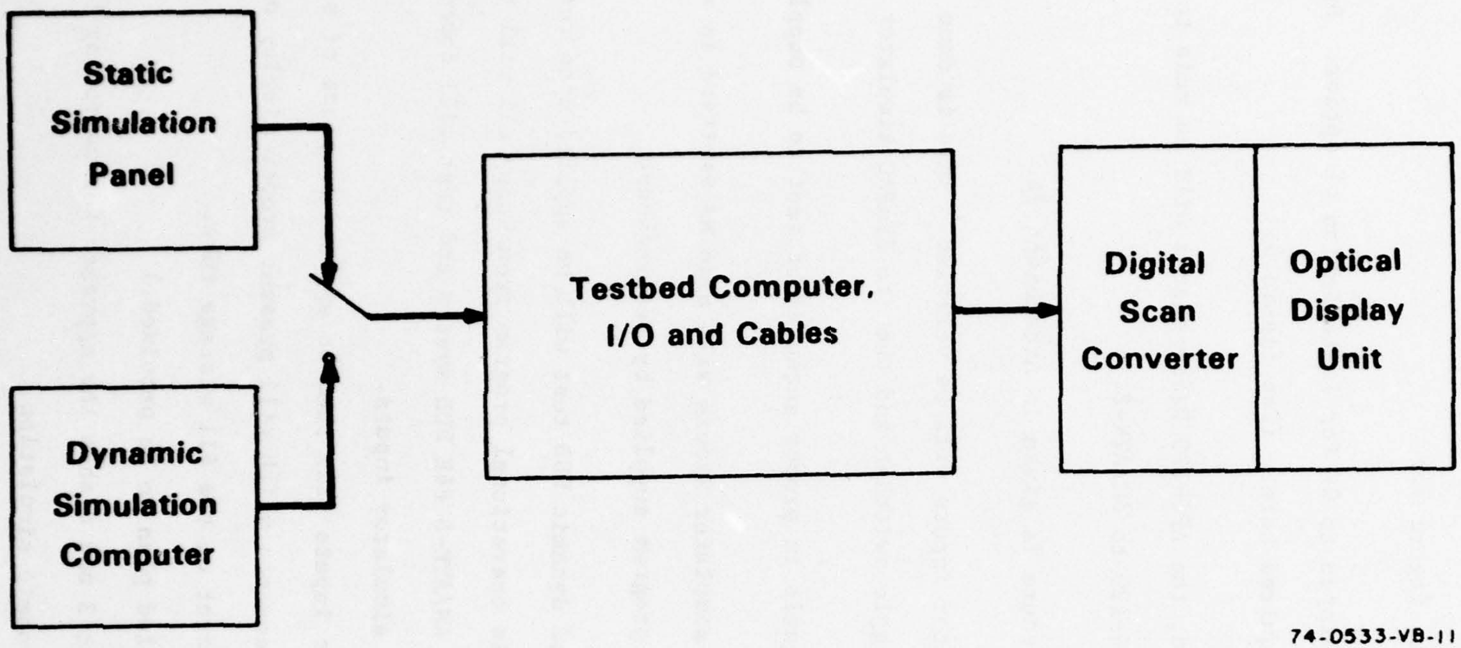


Figure 3

Ground Tests

- ASD/ENA SEAFAC Facility
- Static Simulation
- Dynamic Simulation

74-0533-VA-10

Figure 4

- Additional acceptance tests in accordance with Air Force requirements will be generated and run as required by Capt. Koger.

2. DYNAMIC SIMULATOR PLAN

Westinghouse is to provide a modified AN/AYK-8 computer in which the aircraft and some sensor inputs are simulated by software in the computer. A list of the signals are as follows:

	Signal	Type	Value Range	Scale
1.	Natural Log of static LnPs	DC	0 + 10	.34346 ln units/V
2.	TAS	DC	0 - +10	150 knots/V
3.	Azimuth Rate	DC	-10 - +10	2 deg/s/V
4.	Elevation Rate	DC	-10 - +10	2 deg/s/V
5.	Longitude Acceleration	DC	0 - +5	.8G/V, -2G - +2G
6.	Vertical Acceleration	DC	0 - +5	2.6G/V, -3G - +10G
7.	Lateral Acceleration	DC	0 - +5	1.2G/V, -3G - +3G
8.	Velocity North	DC	±10	150 fps/V
9.	Velocity East AG only	DC	±10	150 fps/V
10.	Velocity Vertical	DC	±10	100 fps/V
11.	Pitch Rate	AC	±1.5	.028V/deg/s
12.	Roll Rate	AC	±1.5	.028V/deg/s
13.	Yaw Rate	AC	±1.5	.028V/deg/s
14.	Angle Attack	AC	-3.68 - +6.5	2.778 deg/V(+[illegible] Nose Up)
15.	Pitch Angle	AC Sync	0 - 11.8	
16.	Roll Angle	AC Sync	0 - 11.8	
17.	Yaw Angle (Heading)	AC Sync	0 - 11.8	
18.	Radar Range	DC	0 - +10	1500 ft/V
19.	Range Rate	DC	±10	150 fps/V (+ opening)
20.	Antenna Angle Azimuth Sine	AC	0 - 15.6	18 sin λ_a
21.	Antenna Angle Azimuth Cosine	AC	9 - 18	18 cos λ_a
22.	Antenna Angle Elevation Sine	AC	0 - 15.6	18 sin λ_e
23.	Antenna Angle Elevation Cosine	AC	9 - 18	18 cos λ_e
24.	Radar Lock	Discrete	0, 28 VDC	
25.	Trigger 1 and 2	Discrete	0, 28 VDC	

Dynamic Input Signal List

- Throttle Control
- Altitude Set Pot
- Reset Push Button
- Y axis hand control

The Air Force will supply the dynamic aircraft flight simulator program, and canned enemy aircraft flight profile to give range, range rate, antenna angle azimuth (sin/cos), and antenna angle elevation (sin/cos).

The sequence of introducing such is as follows:

1. An additional bench is being added to SEAFAC for the HUD program, and another AN/AYK-8 setup was made. This setup will be the software test and validation area for the SEAFAC dynamic simulator software. A complete set of diagnostics will be run to verify computer performance. These new facilities will remain at SEAFAC.

2. Approximately two weeks later, the modified AN/AYK-8 Dynamic Simulater Computer will be installed on the maintenance bench.

3. Westinghouse will supply pots to simulate the hand stick, throttle, reset push button, and altitude pot inputs.

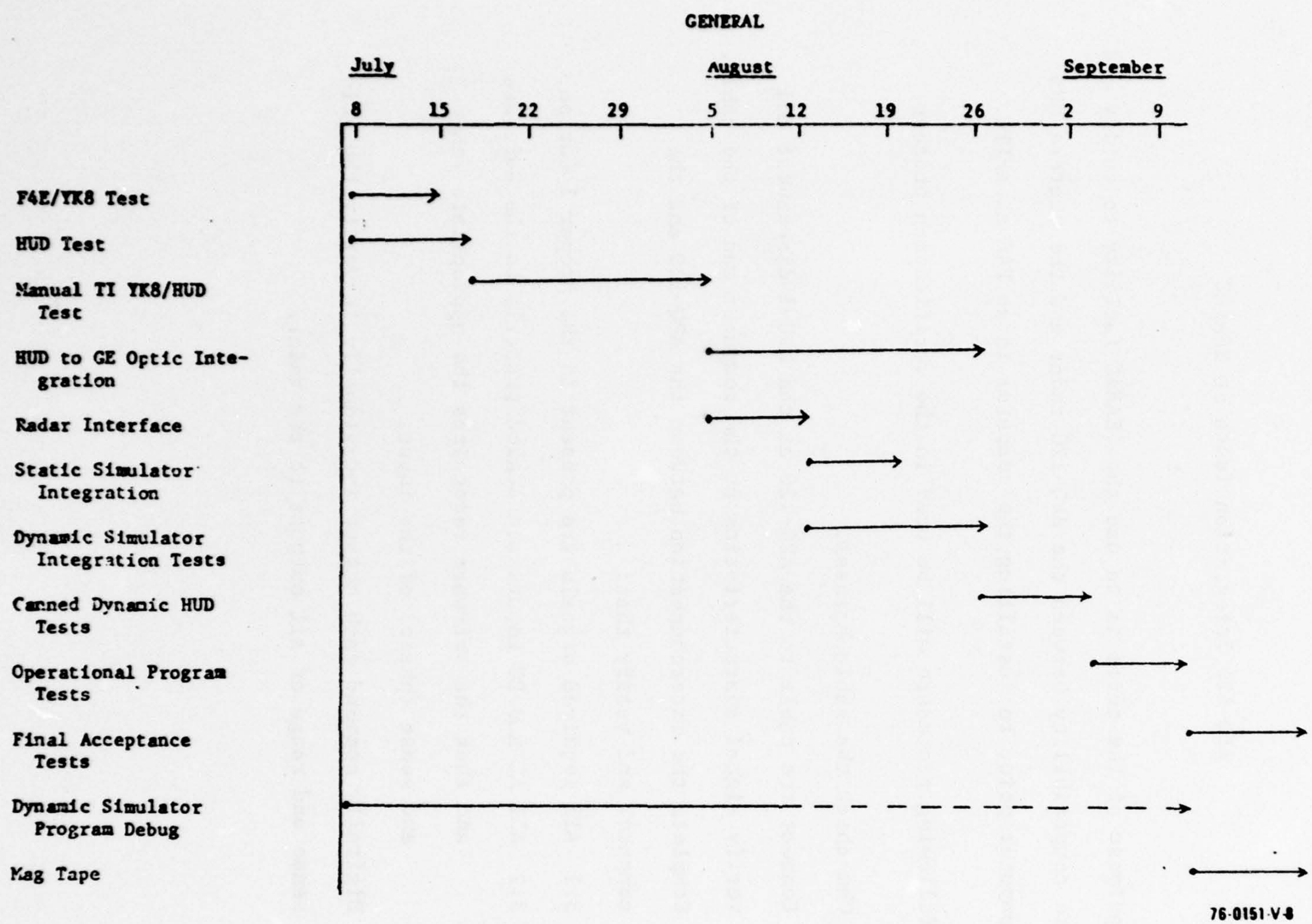
4. The outputs of the simulator computer will be verified according to T Specs supplied by Westinghouse.

5. The operational program will then be installed and tested in the following sequence.

- Program cycles.
- Program display on 611 resets and presents aircraft course and altitude for canned missions.
- Program fixed to give static outputs of known values. Measurements are made to confirm such values.
- Program free runs under control of input throttle, etc.

6. Special Air Force test equipment required:

- None - SEAFAC test equipment appears satisfactory for this test program.


GENERAL
July
August
September
8
15
22
29
5
12
19
26
2
9
F4E/YK8 Test
HUD Test
Manual TI YK8/HUD Test
HUD to GE Optic Integration
Radar Interface
Static Simulator Integration
Dynamic Simulator Integration Tests
Canned Dynamic HUD Tests
Operational Program Tests
Final Acceptance Tests
Dynamic Simulator Program Debug
Mag Tape
76-0151-V-8

Attachment #1

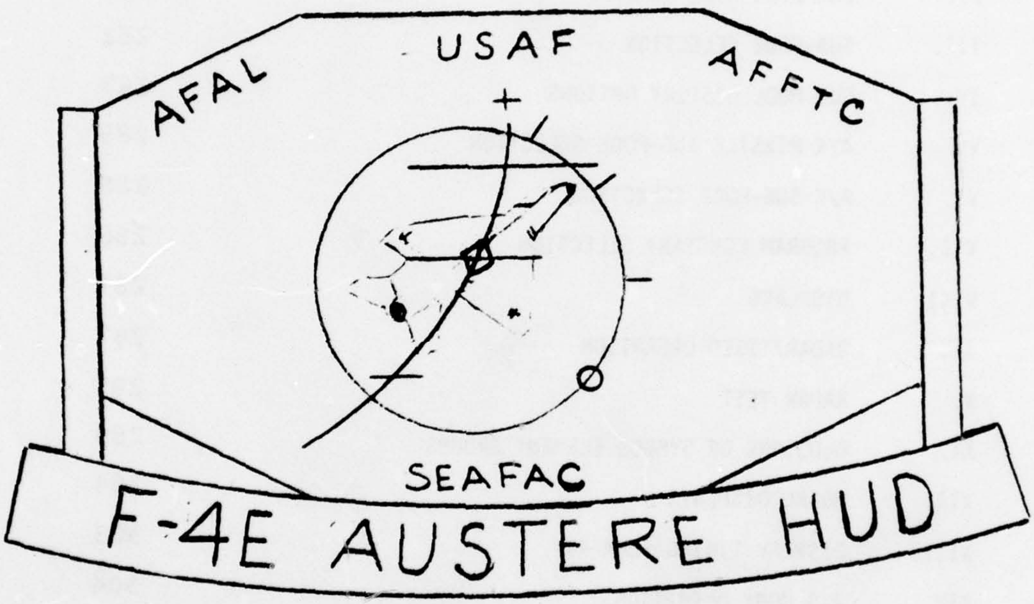
APQ-120 Integration Tests at SEAFAC

The purpose of the tests is to use the SEAFAC facility to verify and demonstrate compatibility between the APQ-120 radar and the Austere HUD digital computer prior to installing the computer in an F4E at AFFTC.

The following procedure will be used in the verification process.

1. Ohm-check the cable harness.
2. Connect the cable to the APQ-120 at the LRU-1 disconnect and verify signal characteristics at the computer end of the cable.
3. Complete the interconnection between the APQ-120 and the computer and verify that:
   3.1 All required signals are present in the proper location.
   3.2 All AC and DC inputs are scaled properly to the software and that the software recognizes the appropriate range and sense (phase) of the input.
4. Digitally command each output individually to verify the gain sense and range of all outputs to the radar.

APPENDIX A8



AUSTERE HUD SYSTEM OPERATION

Westinghouse Electric Corporation
Defense & Electronic Systems Center
Systems Development Division
P. O. Box 746
Baltimore, Maryland 21203

February 5, 1975

AUSTERE HUD SYSTEM OPERATION

TABLE OF CONTENTS

AUSTERE HUD SYSTEM OPERATION

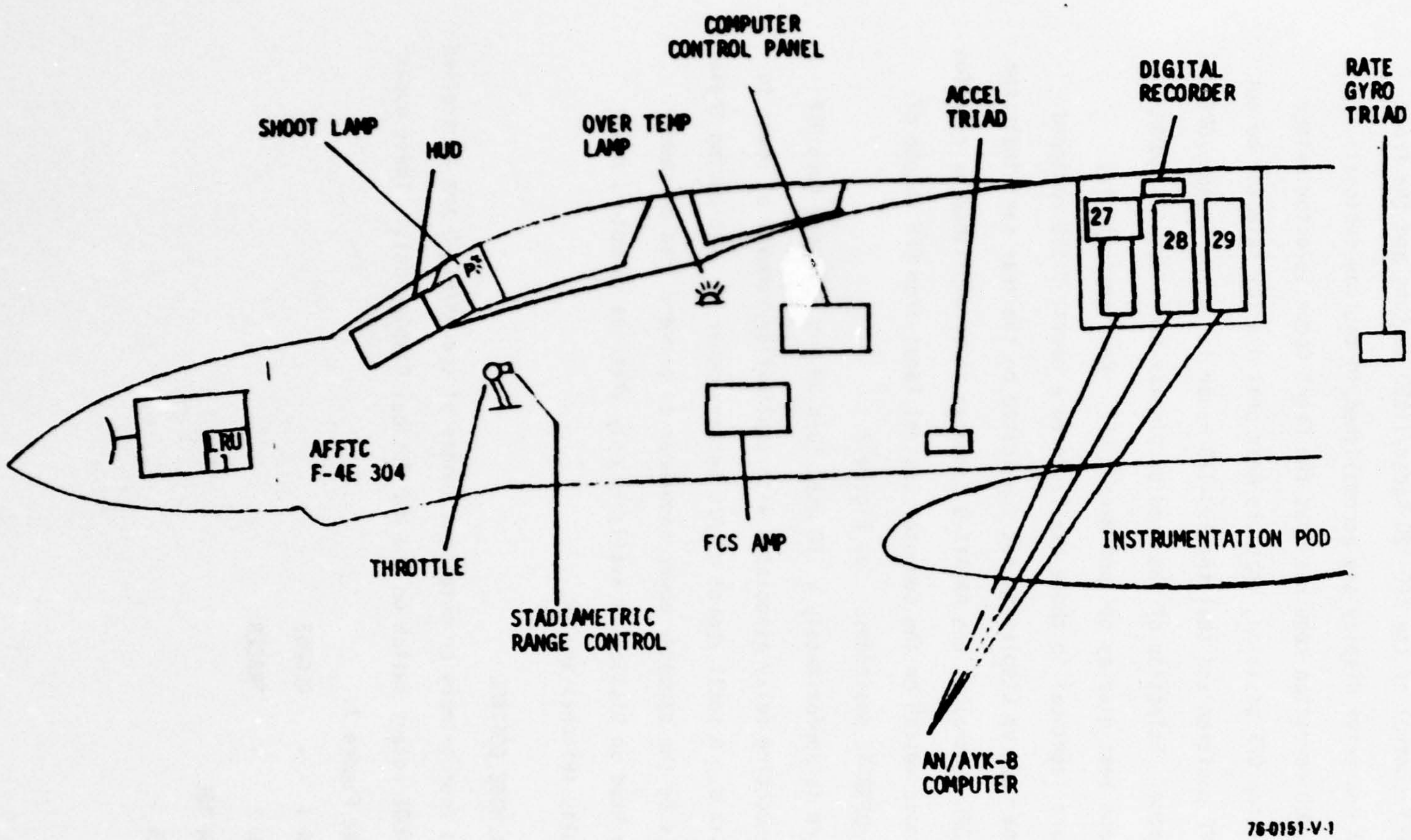
FIGURES

INTRODUCTION

This document provides an operator oriented description of AUSTERE HUD operation in AFFTC F-4E #304.

Figure 1 indicates the relative location of the major components of AUSTERE HUD in the aircraft. The modified AN/AYK-8 computer accepts inputs from associated aircraft avionics, computes the appropriate Gun/Missile/A-G algorithm and through a digital/serial link to the digital scan converter generates the HUD symbology. The symbology is painted on the scan converter CRT and projected up on the combining glass of the HUD Optical Display Unit.

The initial paragraphs describe the mode select capability/process and provide a definition of the Head Up Display symbology associated with AUSTERE HUD. Subsequent paragraphs describe mode operation and AUSTERE HUD algorithms.



AUSTERE HUD INSTALLATION

FIGURE 1

I. SYSTEM ON/OFF CONTROL

ON/OFF control of the APQ-120 Radar/TISEO systems and the front seat Scan Converter Display are accomplished in the conventional manner. HUD operation requires that the Front Scope Selector switch be out of the OFF position, that the Rear seat display selector be out of the OFF position and that the APQ-120 radar is in the Standby/OPERATE or Test mode. Selection of the Head Up Display overrides all RADAR/TISEO front seat display options except OFF. Rear seat display options are identical to those available on a normal TISEO equipped F-4E. The Head Up Display is not duplicated on the rear seat indicator.

ON/OFF control of the AN/AYK-8 Computer is accomplished by rotating the sub-mode switch on the Computer Control Panel from OFF to one of the TEST/OPERATE positions. See Figure 2.

There is approximately a 150 msec turn ON and 715 msec turn OFF power sequencing delay associated with application/removal of power to the AN/AYK-8. A small amount of A/C battery power is used during these intervals by the computer power sequencer to prevent loss of memory.

The Head Up Display is availably only when the computer, radar and display switches are ON.

II. COMPUTER MODE CONTROL

The four primary computational modes of the AN/AYK-8 are controlled by the MODE rotary switch on the HUD Optical Display Unit. These modes are: See Figure 3.

GUN 1 - ALCOSS

GUN 2 - TRACER

A/A MSL

A/G

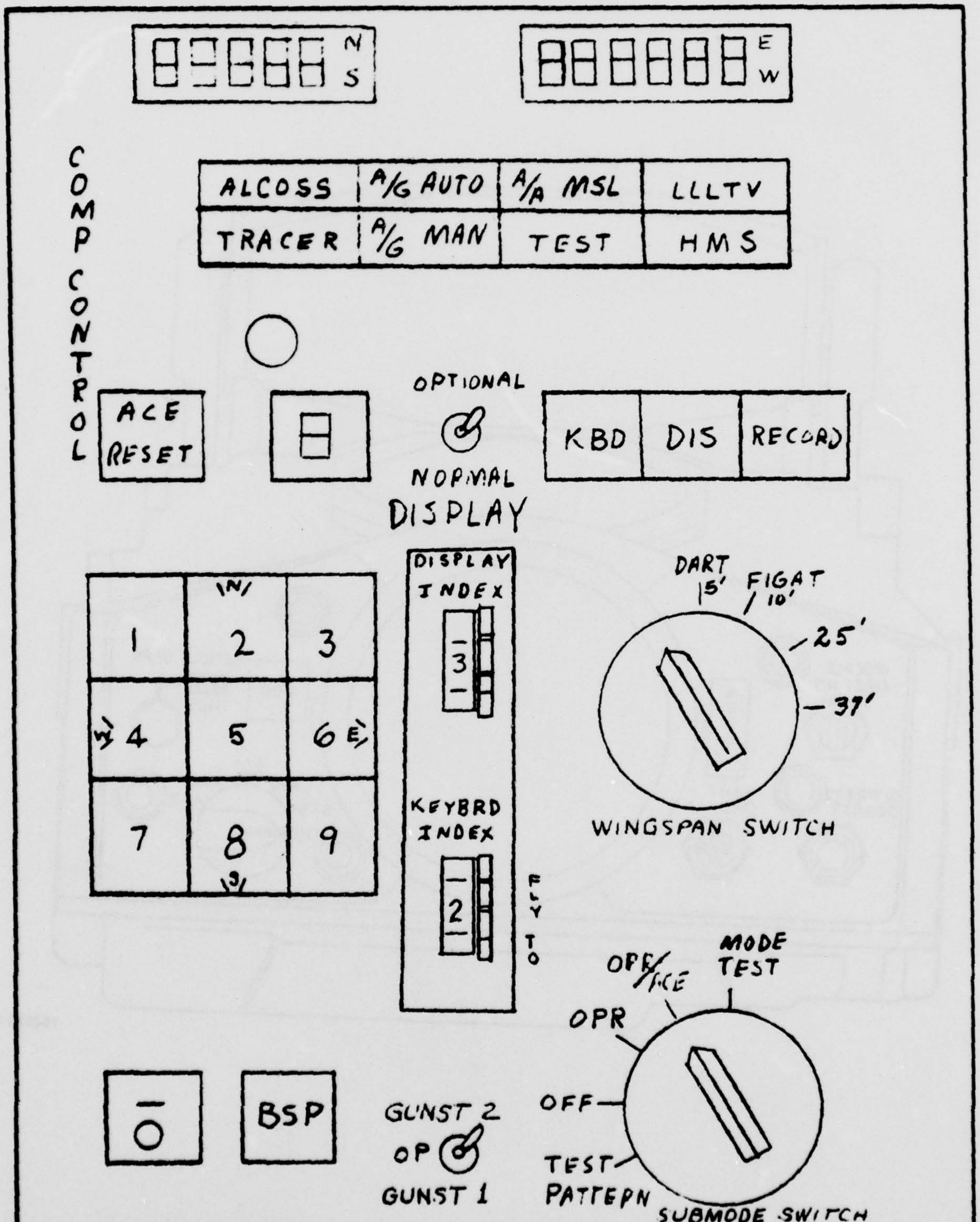


Figure 2. Austere HUD Computer Control Panel

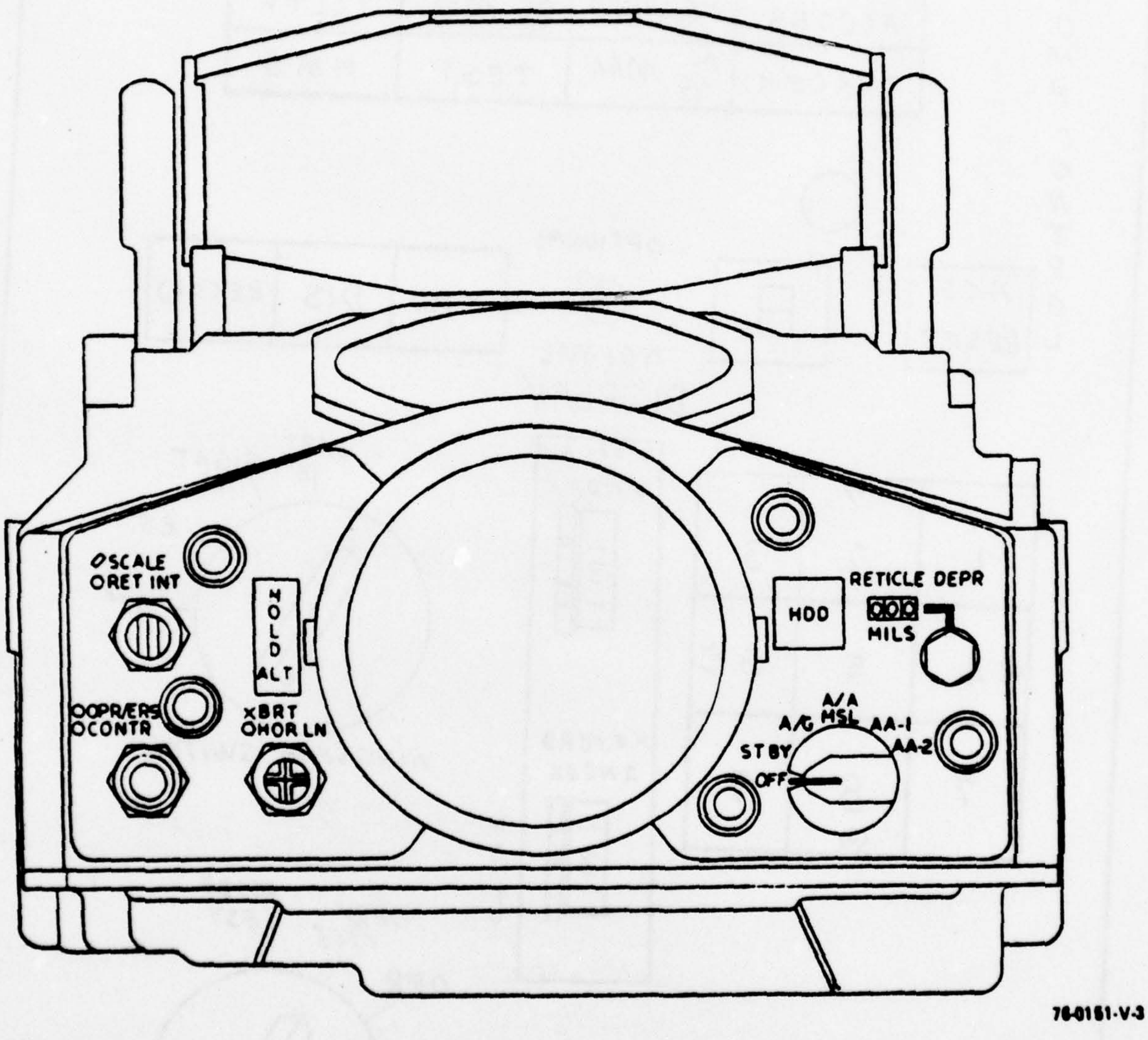


Figure 3. Austere HUD ODU

The selected mode is displayed on the Computer Control Panel (CCP) annunciator lights. The Head Up Display matrix for any combination of HUD mode switch/Computer Control Panel mode switch combinations is shown in Table 1.

HUD MODE SWITCH	CCP MODE SWITCH				
	TEST PAT	OFF	OPR	OPR/ACE	MODE TEST
OFF	BLANK	BLANK	BLANK	BLANK	BLANK
STBY	TEST PAT	BLANK	GUN CROSS	GUN CROSS	GUN CROSS
A/G	TEST PAT	BLANK	A/G^{o}	A/G^{o}	A/G TEST
A/A MSL	TEST PAT	BLANK	MSL	MSL	MSL TEST
AA-1	TEST PAT	BLANK	ALCOSS	ALCOSS	ALCOSS TEST
AA-2	TEST PAT	BLANK	TRACER	TRACER	TRACER TEST

TABLE 1. AUSTERE HUD DISPLAY MATRIX

III. SUB-MODE SELECTION

As noted in Table 1, the following Rear Seat submode options are selectable in the four primary AUSTERE HUD Modes, TEST PATTERN, OPERATE, OPERATE/ACE, and MODE TEST.

A. OPERATIONAL PROGRAM SELECTION

The operational program for the four primary modes is selected by rotating the sub-mode switch on the Computer Control Panel to "OPR". The program automatically uses live inputs except when a gun mode (TRACER/ALCOSS) is selected on the HUD mode switch. Live inputs to the gunnery computations are obtained by additionally selecting "OP" on the CCP Gun Test switch.

B. OPERATIONAL PROGRAM WITH ACE

The operational program including ACE for TRACER and ALCOSS, is obtained by selecting "OPR/ACE" on the Computer Control Panel sub-mode switch.

C. TEST PATTERN

A static test grid on the HUD is obtained by selecting "TEST PATTERN" on the Computer Control Panel sub-mode switch. This option overrides all front seat mode display options.

D. MODE TEST

A dynamic, mode oriented HUD test display is obtained by selecting "MODE TEST" on the Computer Control Panel sub-mode switch. Dynamic inputs are canned into the display routine.

IV. GUN MODE DISPLAY OPTIONS

The following rear seat options are available when either ALCOSS or TRACER are selected on the HUD mode switch.

A. GUN TEST

"OP" provides live inputs to the TRACER and ALCOSS gunnery routines.

TEST 1 provides fixed digital inputs to the TRACER and ALCOSS routines.

Roll Rate = 0	
Pitch Rate = +6 Deg/Sec	Closing Rate = 0
Yaw Rate = +3 Deg/Sec	Angle-of-Attack = 0
3 Axis Accel. = 0 ft/Sec^2	TAS = 844 ft/Sec
Altitude = 10K ft.	M = 0.784
	Range = 2500 ft

TEST 2 provides digital inputs to the TRACER and ALCOSS routines. All inputs are fixed except range, which is programmed to vary between 600 and 2500 feet. The switch is functional only

if either "OPR" or "OPR/ACE" is selected on the CCP. It has no affect in modes other than gunnery.

B. WING SPAN

Wing span selection for stadiametric/fixed ranging in the ALCOSS and TRACER modes is made by setting the Wing Span switch on the Computer Control Panel to the appropriate position, i.e. 5' DART, 10' FIGAT, 25' and 37'.

C. ACE RESET

Set-up conditions for initializing the TRACER/ALCOSS Air Combat Evaluator (ACE) modes are obtained by depressing and releasing the "ACE RESET" switch on the Computer Control Panel.

D. RECORD

Digital recording of selected input/output and intermediate values is initiated by depressing and releasing the "RECORD" switch on the Computer Control Panel. The RECORD annunciator lamp will be lighted while record is in process. Depressing and releasing the record switch a second time halts the RECORD process and extinguishes the lamp. Record will also be initiated at the second Gun/Missile trigger detent. Analog recording is initiated by the Trigger detent only.

NOTE: The Armament Safety Override and the Right Main Gear Switch must be activated to enable the trigger switch with the aircraft on the ground.

E. RANGE

The range input used by the ALCOSS and TRACER algorithms is from one of three sources, fixed, radar or stadiametric. The software program selects the appropriate source as a function of the conditions established in Table 2.

STADIAMETRIC RANGE CONTROL IN DETENT POSITION	RADAR RNG LOCK	
	YES	NO
YES	RADAR	FIXED 1500'
NO	STADIAMETRIC	STADIAMETRIC

TABLE 2. GUNNERY PROGRAM RANGE INPUT SELECTION

F. OPTIONAL INPUTS

The optional set of rates and accelerations from the Flight Control System is not manually selectable for use by the operational gunnery programs. These inputs will be recorded.

G. OPTIONAL DISPLAY SYMBOLOGY

Optional Display Symbology for all modes is obtained by switching the "OPTIONAL/NORMAL" display switch on the Computer Control Panel to OPTIONAL.

V. A/A MISSILE SUBMODE SELECTION

No submode (other than optional display) is selectable. A Sparrow/Sidewinder (RDR/HEAT) discrete is brought into the computer but not used. The program is set up to compute Long Range Intercept (LRI) displays for one missile only. No missile outputs are provided. The record option is the same as in gunnery.

VI. AIR-TO-GROUND SUBMODE SELECTION

Two Air-to-Ground submodes are selectable:

A. A/G Manual - A canned approach bombing program for display evaluation only is available by selection of A/G on the HUD and "DIRECT" on the LABS Weapon Select Panel. The technique for changing the release conditions is described in subsequent paragraphs.

NOTE: The Armament Safety Override switch must be activated to select this mode when the aircraft is on the ground.

B. A/G Automatic - An A/G CCIP program responsible to aircraft inputs is available by selecting A/G on the HUD and any position except "DIRECT" on the LABS Weapon Select Panel. Release is manual. The program is for display evaluation only since the simplified program assumes a vacuum drop.

VII. PROGRAM CONSTANT SELECTION

Constants stored in the program for various computational modes, e.g.:

ALCOSS/TRACER	-	Initial Rounds
A/G MANUAL	-	Canned Release Conditions
A/G AUTOMATIC	-	Target Altitude

can be changed by the following sequence of operations utilizing the CCP keyboard:

1. Select appropriate Keyboard Index number.
2. Depress and Release "Keyboard".
3. Enter the appropriate digit(s) on the Keyboard.
4. The number entered will appear on the right side digital display.
5. If the number displayed is wrong, depress Back Space "BSP" and re-enter the correct digit(s).
6. If the number displayed is satisfactory, depressing and releasing the "Keyboard" switch changes the program constants.

To determine the values currently being used by the program:

1. Select the appropriate "Display Index" number.
2. Depressing and releasing the display (DIS) switch will cause the appropriate value to appear on the right side digital display.

Flight Cards will be used to correlate the digital display number with actual program constants for each index position.

VIII. DISPLAYS

A complete description of the HUD symbology generation is contained in a separate AUSTERE HUD report. Selection of Head Up display on the HUD Optical Display Unit front panel will cause these displays to appear on the ODU combining glass and on the front scope CRT. The Head Up position automatically overrides the "Front Scope Selector" switches and prevents a front scope display of radar or TISEO Video. Rear scope display and selection is always normal for a TISEO configured aircraft. Depressing HDD, Head Down Display, on the ODU front panel causes a backup reticle to appear on the combining glass and redirects control of the front scope CRT display to the normal options available on the Front Scope Selector switch.

IX. RADAR/TISEO OPERATION

Radar/TISEO operation in the aircraft subsequent to incorporation of AUSTERE HUD is normal except for the aforementioned Front Scope display selection.

X. RADAR TEST

All APQ-120 BIT tests exclusive of the LRU-1 missile computation functional tests will operate normally. Functional tests of the Sparrow and Falcon missile computations will not be run.

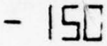
TEST	DISPLAY RESPONSE				
DOT BALANCE	NORMAL				
BIT SELECTED	DOT	ASE	Rmax	Rmin	V_C Gap
BIT 1	-*	-	-	-	Normal CW Coding & Ranging
BIT 2	-	-	-	-	
BIT 3	Normal for Angle Track Test	Normal			Normal
BIT 4	-	-	-	-	Normal for SIM DOP Test
BIT 5	-	-	-	-	-
BIT 6	-	-	-	-	-

*- Indicates that these displays convey no meaningful information.

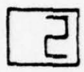
:I. GLOSSARY OF SYMBOL ELEMENT GROUPS

The symbol element groups utilized in the various mode displays are briefly described below:

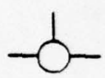
Gun Cross - Indicates the direction of the ADL.



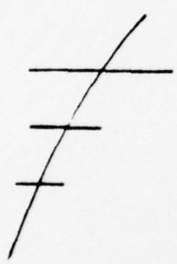
Range Rate - Time rate of change of radar range in knots.



Rounds Remaining - Indicates the number of rounds of gun ammunition remaining in hundreds of rounds.

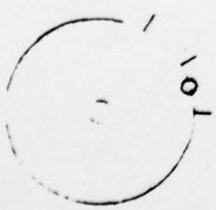


Velocity Vector - Indicates the direction of the true air speed vector or the ground speed vector, as determined by mode selection.



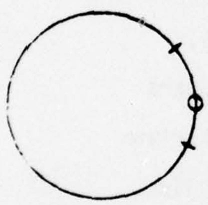
Tracer Line and Range Bars - Indicates bullet trajectory as seen through the HUD. Included with the tracer line are stadiametric range bars located at points on the line corresponding to 1000, 2000 and 3000 feet of range and sized to correspond to the selected wing span at these ranges.

Tracer Line Range Markers - When radar mode is selected the diamond is placed on the tracer line at the point corresponding to radar range. When manual mode is selected a circle, sized to correspond to the selected wing span and the manual range input, is placed on the tracer line at the point corresponding to the manual range input.

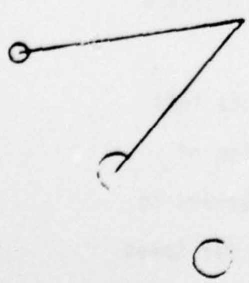


ALCOSS Aiming Reticle - This symbol consists of a 6 mil dia. piper circle and a large concentric reticle circle which also serves as a range scale. The location of the

center of these circles indicates the computed aim point to be placed on the target. When radar mode is selected the large reticle circle has a 50 mr diameter. When manual mode is selected the reticle circle is stadiametrically sized to correspond to the selected wing span at the manual range input. Fixed 4 mil range bars are located at 1, 2 and 3 o'clock positions on the reticle circle corresponding to 1000, 2000 and 3000 feet of range. A 4 mil dia. circle centered on the reticle indicates either radar range or the manual range input.

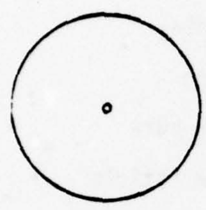


Missile Mode Reticle - This is a 50 mil dia. reticle circle centered on the gun cross. It serves as a range scale where zero range is at the 12 o'clock position. Radar range is indicated on this scale by a 4 mil dia. circle centered on the reticle circle and placed at an angle corresponding to a scale factor of 1 degree per 100 feet of range, measured clockwise. Missile minimum and maximum allowable launch range are also displayed as 4 mil range bars with angular position based on this scale factor. Maximum display range is 27K ft.

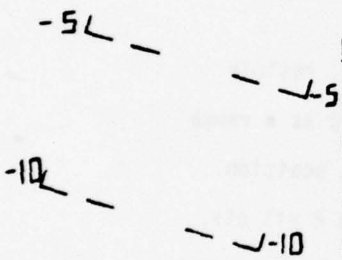


Target Designator - This symbol is a 10 mil dia. circle indicating the direction of the line-of-sight to the target. If the LOS is in the total FOV but outside the instantaneous FOV, a line joins the center of the circle and the Gun Cross. If the LOS is outside the total FOV the line terminates at the boundary of the total FOV and a 5 mil dia. circle replaces the 10 mil dia. circle and is placed at the line termination.

<u>Steering Bug</u> - Indicates the direction of the computed steering course, achieved by flying the plane to place the Velocity Vector symbol over the Steering Bug.

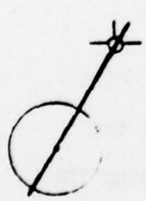


<u>Sight Reticle</u> - Consists of 50 mil reticle and concentric 2 mil piper. Center of circles indicates aim point to be placed over target in Air-to-Ground Modes. When Manual Mode is selected the reticle is set to a preselected depression angle below the Fuselage Reference Line. When Automatic Mode is selected the reticle indicates the Continuously Computed Impact Point (CCIP).



<u>Pitch Lines</u> - Lines drawn parallel to the horizon line and separated by 5 degree increments. Positive pitch lines have wings or tabs directed toward horizon (down), negative lines have a break and wings directed toward horizon (up). Pitch angle of each line, except horizon line is indicated by numerals at each end of the line.

<u>Reference Dive Angle Indicator</u> - Indicates selected dive angle in Air-to-Ground Manual Mode. Not roll sensitive. Selected dive angle achieved when Velocity Vector symbol and Reference Dive Angle Indicator are aligned.



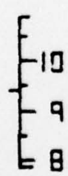
<u>Bomb Fall Line</u> - Line joining Velocity Vector symbol and Sight Reticle in Air-To-Ground Automatic Mode to indicate the track of a stick of bombs.

<u>Reference Air Speed Scale</u> - A verticle scale at the left in the HUD FOV, when displayed, indicating deviation of True Air Speed from a preset value. The three markers to the left of the vertical line are: the Reference Air Speed indexed at the center, and the upper and lower scale limits

(± 50 knots). The right hand marker indicates deviation from the Reference Air Speed.

<u>Reference Altitude Scale</u> - A vertical scale at the right of the HUD FOV, when displayed, indicating deviation of altitude from a preselected value. Upper and lower scale limit markers (± 1000 ft.) and an altitude reference index, representing the selected altitude, are displayed on the right side of the scale. The current altitude deviation from the reference is indicated by the marker on the left side of the scale.

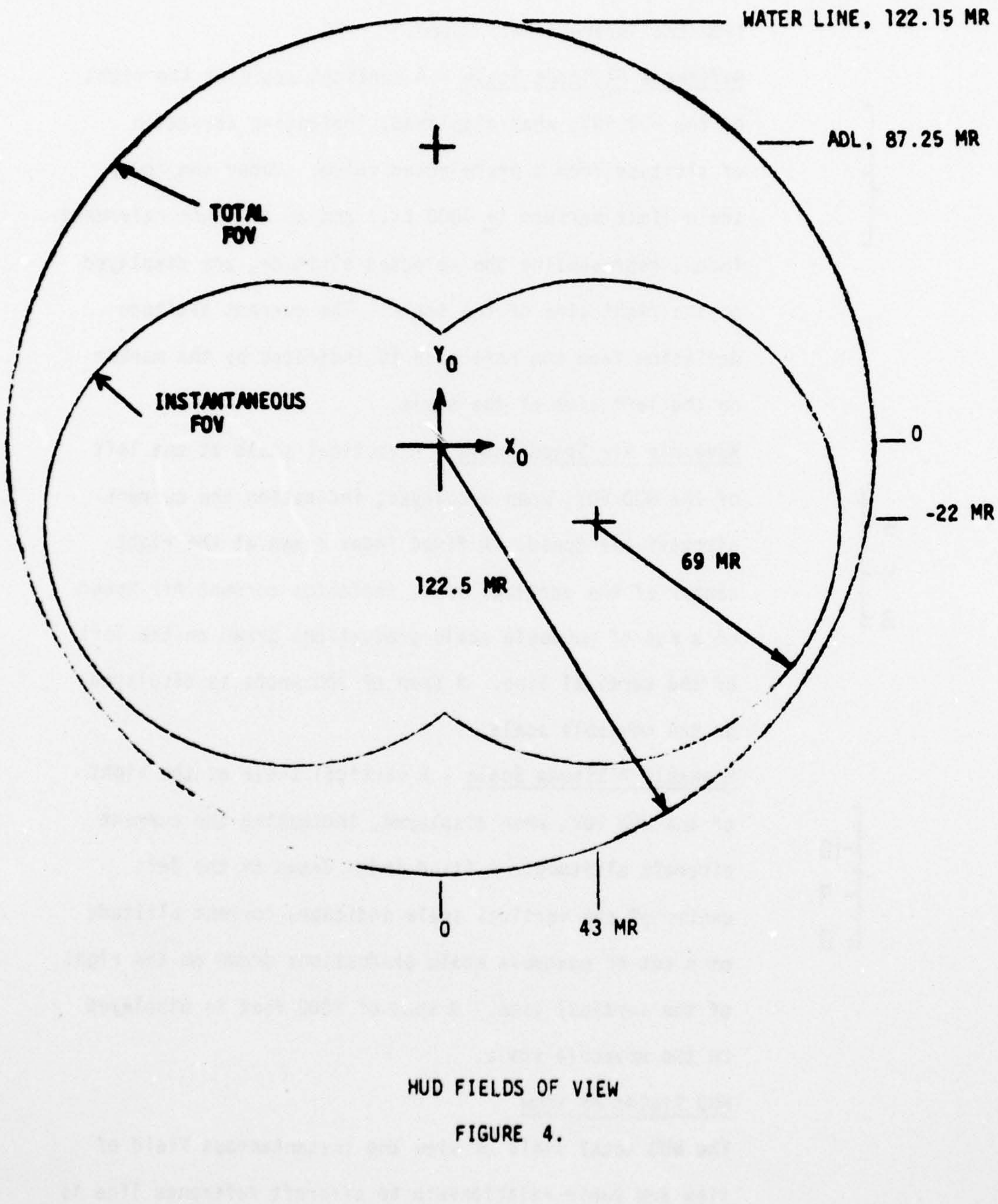
<u>Moveable Air Speed Scale</u> - A vertical scale at the left of the HUD FOV, when displayed, indicating the current aircraft Air Speed. A fixed index drawn at the right center of the vertical scale indicates current Air Speed on a set of moveable scale graduations drawn on the left of the vertical line. A span of 300 knots is displayed on the moveable scale.



<u>Moveable Altitude Scale</u> - A vertical scale at the right of the HUD FOV, when displayed, indicating the current aircraft altitude. A fixed index drawn at the left center of the vertical scale indicates current altitude on a set of moveable scale graduations drawn on the right of the vertical line. A span of 3000 feet is displayed on the moveable scale.

<u>HUD Fields of View</u>

The HUD total field of view and instantaneous field of view and their relationship to aircraft reference line is illustrated in Figure 1.



HUD FIELDS OF VIEW

FIGURE 4.

XII. MODAL DISPLAYS

Illustrations of the symbol groups currently utilized in the various modal displays are shown in Figures 2 through 7. These are briefly described below:

A. AIR-TO-AIR, GUNS, TRACER - FIGURE 2

The standard symbol set for this mode display includes:

1. Gun Cross
2. Velocity Vector
3. Rounds Remaining
4. Range Rate
5. Tracer Line and Stadiametric Range Bars
6. Present Range Indicator

The Rounds Remaining symbol is only displayed when 200 rounds of gun ammunition or less remain and then the symbol displayed is $\boxed{2}$.

When a radar mode is selected the range indicator is the diamond. When manual mode is selected the range indicator is the stadiametrically sized circle.

When the optional symbol set is selected the standard set, above,is displayed except that the Rounds Remaining symbol indicates the number of rounds in hundreds.

B. AIR-TO-AIR, GUNS, ALCOSS - FIGURE 3

The standard symbol set for this mode display includes:

1. Gun Cross
2. Velocity Vector
3. Rounds Remaining

4. Range Rate

5. ALCOSS Aiming Reticle

The Rounds Remaining symbol is only displayed when 200 rounds of gun ammunition or less remain and then the symbol displayed is $\boxed{2}$.

When the optional symbol set is selected the standard set, above, is displayed except that the Rounds Remaining symbol indicates the number of rounds in hundreds.

C. AIR-TO-AIR, MISSILE - FIGURE 4

The standard symbol set for this mode includes:

1. Gun Cross
2. Velocity Vector
3. Steering Bug
4. Missile Mode Reticle
5. Range Rate

In addition a cockpit SHOOT light is energized when missile launch conditions are satisfied.

When the optional symbol set is selected the Target Designator and Moveable Altitude Scale are displayed in addition to the standard set.

D. AIR-TO-GROUND, MANUAL - FIGURE 5

The standard symbol set for this mode includes:

1. Gun Cross
2. Velocity Vector
3. Sight Reticle
4. Reference Dive Angle Indicator
5. Reference Air Speed Scale
6. Reference Altitude Scale

E. AIR-TO-GROUND, CCIP - FIGURE 6

The standard symbol set for this mode includes:

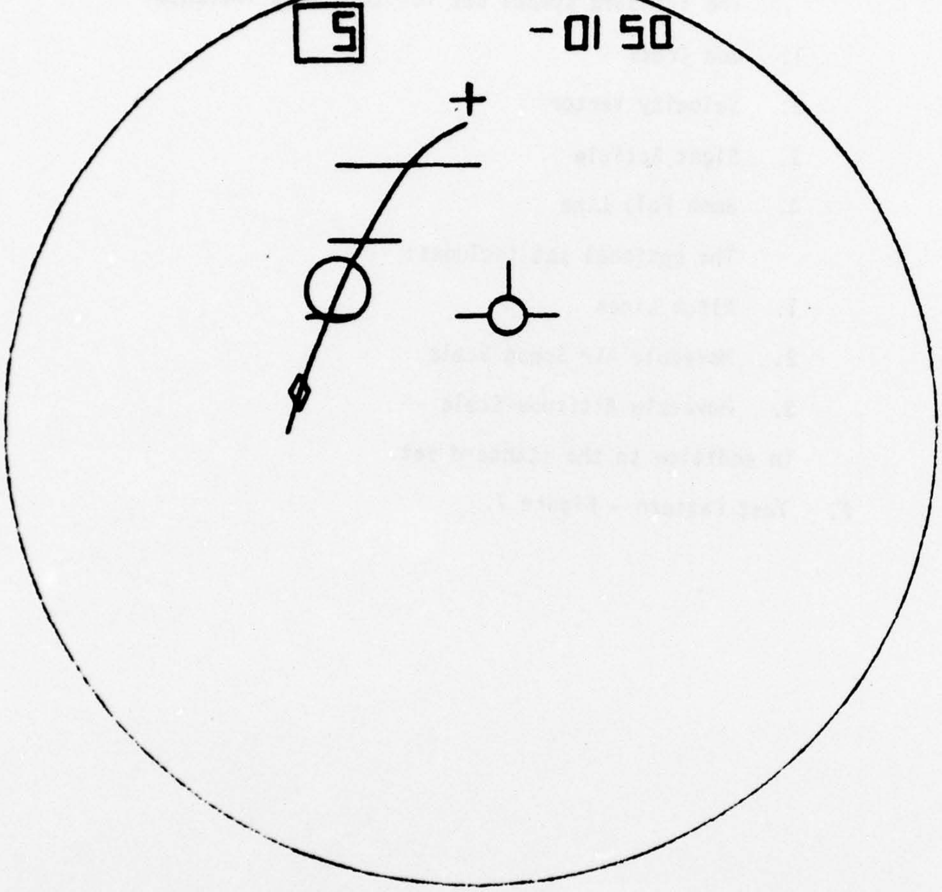
1. Gun Cross
2. Velocity Vector
3. Sight Reticle
4. Bomb Fall Line

The optional set includes:

1. Pitch Lines
2. Moveable Air Speed Scale
3. Moveable Altitude Scale

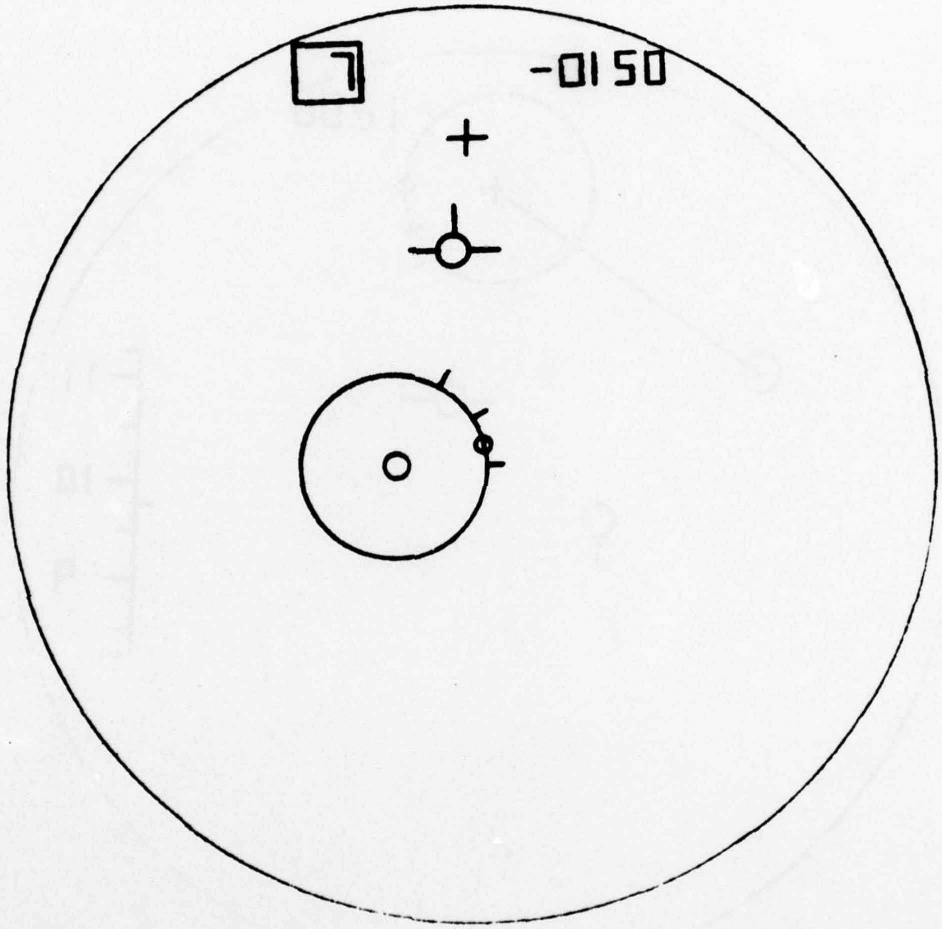
in addition to the standard set.

F. Test Pattern - Figure 7.



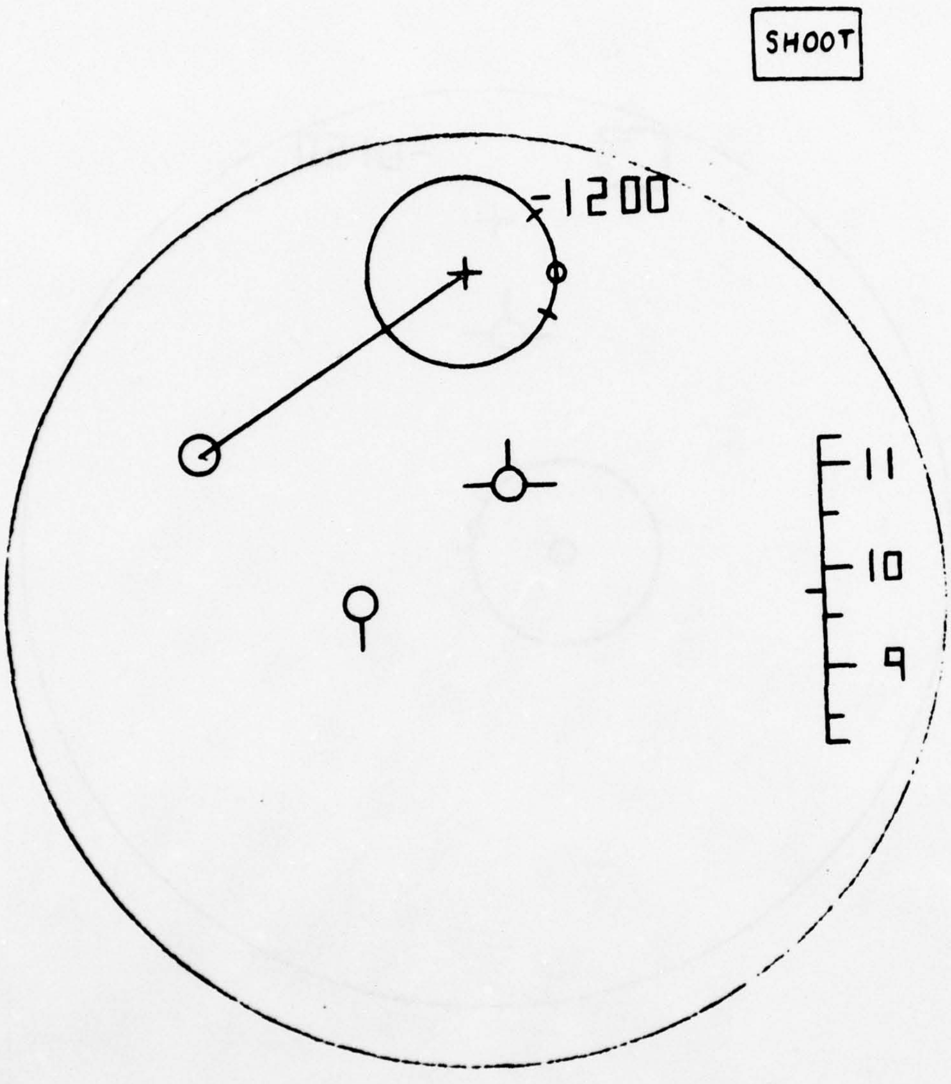
AIR TO AIR, GUNS
TRACER

FIGURE 5.



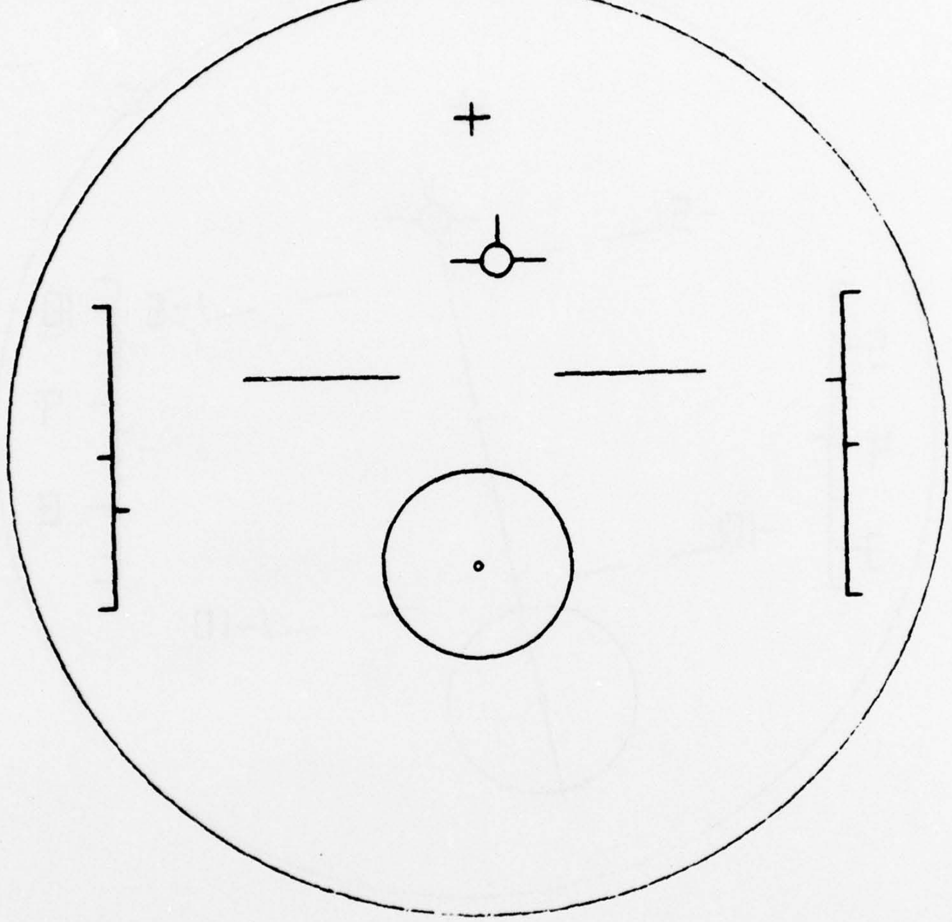
AIR TO AIR, GUNS
ALCOSS

FIGURE 6.



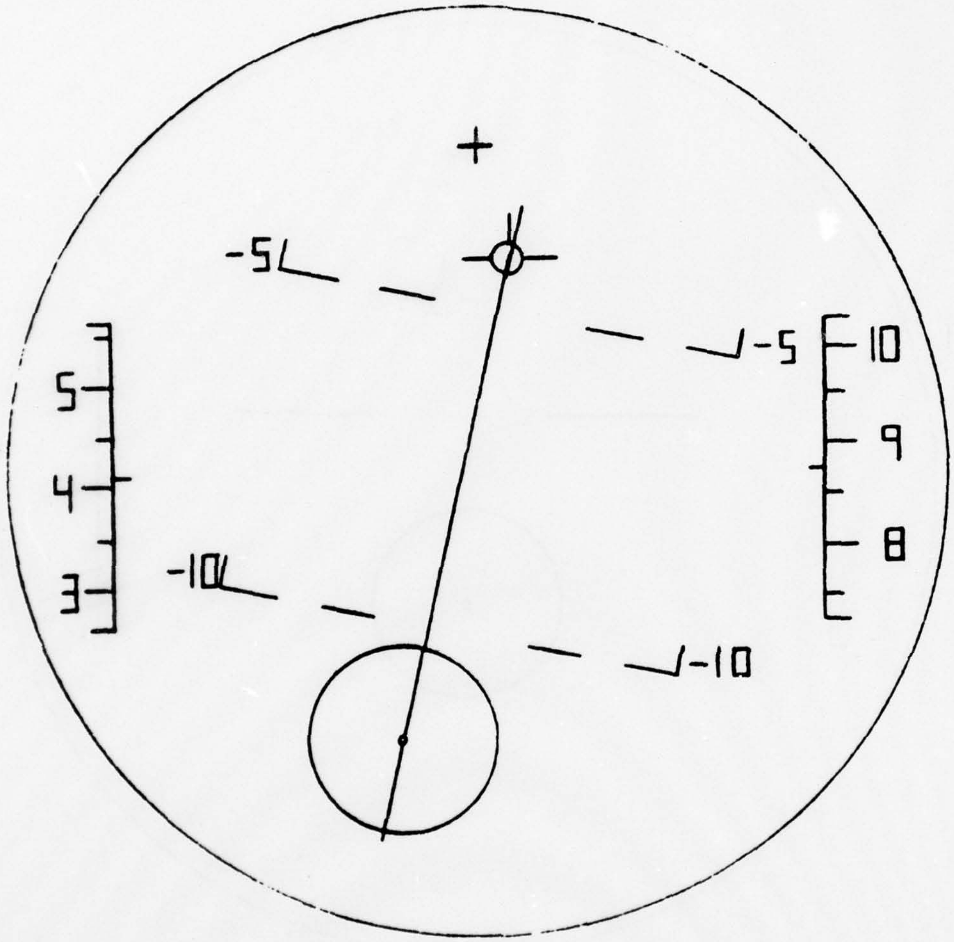
AIR TO AIR, MISSILE

FIGURE 7.



AIR TO GROUND, MANUAL

FIGURE 8.



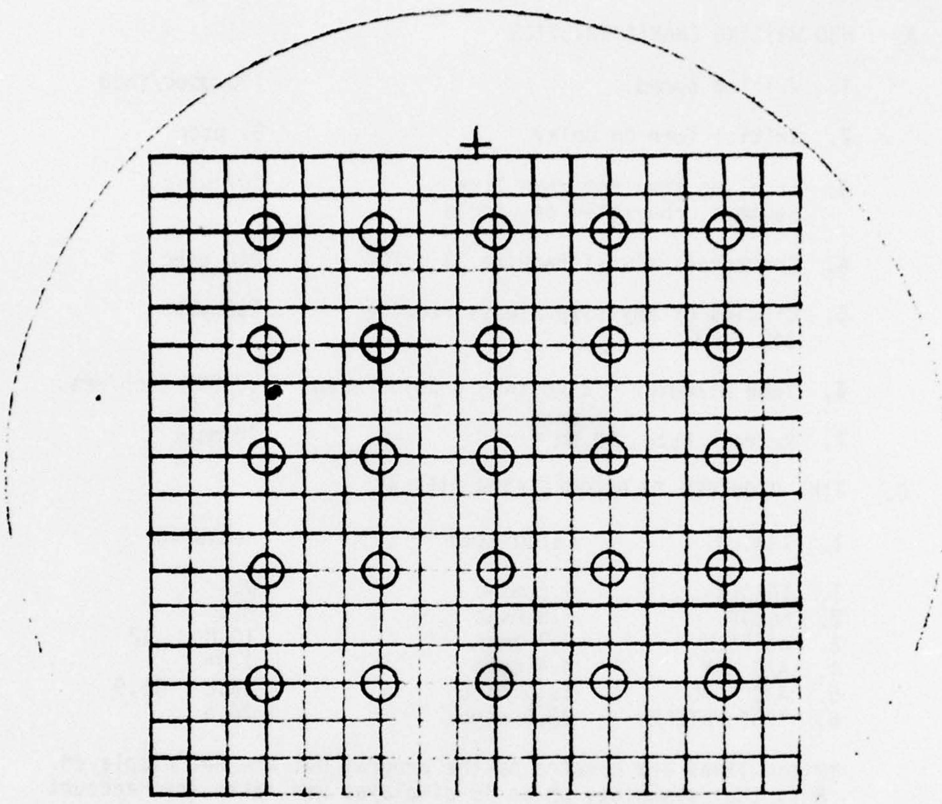
AIR TO GROUND, CCIP

FIGURE 9.

AD-A042 255 WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 19/5
F-4E FIRE CONTROL SYSTEM SIMULATOR, F-4E AUSTERE/HEADS UP DISPL--ETC(U)
MAY 77 W PATTERSON F33615-74-C-1173

UNCLASSIFIED AFAL-TR-76-190 NL

4 OF 5
AD
A042255



Test Pattern

Figure 10.

XIII. DISPLAY TIMING SUMMARY

A. HUD WRITING CHARACTERISTICS

1.	Writing speed	100 μsec/inch
2.	Initial Turn On Delay	81 μsec
3.	Settling time for each line segment, character or circle	207 μsec
4.	Characters always require 33 + 207	240 μsec
5.	Circles of any size always require 345 + 207	552 μsec
6.	Tube Diameter = 2.76 inch = 251.1 mrad	.01099 inch/mrad
7.	Refresh Rate, 50 Hz	20 msec

B. TIME REQUIRED TO PRODUCE EACH DISPLAY

1.	TRACER	Calculated	Measured	
1.	TRACER	9.2 msec	9.1	
2.	ALCOSS	6.5 msec	6.5	
3.	MISSILE	9.9 msec	10.8	12
4.	A/G MAN	4.4 msec	7.9*	
5.	A/G AUTO	16.0 msec	15.8	16.9
6.	TEST PATTERN	28.5 msec	28.5	

*Pitch lines are created by the program but are not displayed. Only that symbology which is displayed was taken into account in the calculated time.

C. MODE SYMBOLOGY

Mode Symbology was selected and limited to that which could be produced within the fixed 20 msec refresh rate. If the amount of time required to produce the symbology exceeds the refresh time, an uneven symbol intensity will result. The same symbol won't be cheated on refresh each time. Exceeding the refresh time by a small amount will cause a "milky", pulsating intensity, although each one will always be visible to the eye. Carrying it to the extreme will cause random visible blinking on and off of all symbols.

D. CHANGE IN REFRESH TIME

Based on the calculated times it would appear that the refresh rate could be changed to 100 Hz (10 msec) for all modes except A/G MANUAL. The Test Pattern can be changed if that proves troublesome.

It has previously* indicated that the 207 usec settling time (which accounts for about one-half the total time in each mode) could be reduced to either 155 or 103 usec. This would however, result in less stable display symbology.

*AFAL, GE, WEC, T.I. meeting at T.I. on 5 June 1974.

XIV. A/G MODE OPERATION

Two basic Air-to-Ground Weapon delive., modes are implemented in the computer, A/G MANUAL and A/G AUTO.

A. A/G AUTO

In spite of what the label "AUTO" seems to imply, both modes require manual release. "AUTO" in this instance only means that the pipper position (Impact Point) is continuously computed and adjusted as a function of aircraft inputs to the computer. It is an aided visual bombing mechanization. The pipper always indicates the point of bomb impact on the ground if released at any given instant, unless the computed impact point is below the field of view of the HUD. When the computed impact point is below the HUD FOV, the pipper is roll stabilized at 70 mil rad to reduce the pendulum effect when rolling in on a target and ease the job of trying to hold the pipper on target. No particular constraints are placed upon the AC to maintain a particular air speed, dive angle or release altitude, while trying to get the pipper on the target.

In normal operation the AC will roll in somewhere above release altitude (10K ft) and establish a dive into the target visible to him through the HUD combining glass. The pipper will stay at the roll stabilized position until the altitude above target decreases sufficiently to place the impact point in the HUD FOV, at which time the pipper will drop to the bottom of the display. As the altitude above target continues to decrease, the pipper will walk up the display. There is no pull up warning (blast fragmentation or ground impact) implemented in this mechanization. Pull up is at pilot discretion. When pull up is initiated the computed impact point can again be expected to fall below the HUD FOV, causing the pipper to return to its roll stabilized position.

The computation is a simple vacuum release* algorithm intended to facilitate display evaluation only. High and log drag bombs, rockets and feathers are treated as one. Drag coefficients for various bomb types, thrust characteristics for propelled weapons, ejection velocities, rack delays, etc. are all ignored for this display evaluation and would have to be considered (along with a means of selecting weapon types) before attempting an actual release.

Altitude above the target is computed barometrically based upon the CADC L_nP input and preset (by means of the CCCP Keyboard) target altitude. Altitude above target could be computed using radar slant range and pointing angle, however, that would require computer control of the antenna pointing angle, and is not mechanized.

*Drag effect on the pipper depression angle is simulated by using only 92% of the computed Horizontal impact range in the pipper computation.

Basic inputs utilized by the pipper computation are:

SIGNAL	SOURCE	USAGE
LnP	CADC	ALTITUDE above S.L.
TARGET ALT	CCCP KEYBOARD	Target Altitude above S.L.
Ground Speed	INS	Impact Point
HEADING	INS	Rotate N,E,V velocity into space X,Y,Z coordinates
PITCH/ROLL	INS	Rotate Impact Point from space to aircraft coordinates

With respect to the rest of the A/G Auto display symbology:

1. The altitude scale displays aircraft altitude above sea level, (not above target).
2. The airspeed scale is TAS, (not ground speed).
3. The pitch lines are pitch angles (not dive) referenced to the aircraft waterline, top of the FOV.
4. The velocity vector indicates dive angle and its position is a function of ground speed.
   a. Vertical displacement is a function of vertical velocity in aircraft coordinates, i.e., $\frac{V_{gn}}{V_g}$, not TAS and α_T.
   b. Lateral displacement is a function of the cross wing ground speed, i.e., $\frac{V_{gm}}{V_g}$, not side slip.

Dive angle is read by interpolating the position of the velocity vector with respect to the referenced pitch lines.

The bomb fall line is drawn between the velocity vector and the pipper when the release condition is within the HUD FOV.

B. A/G MANUAL

The A/G Manual bombing technique is essentially the same as IRON sight bombing. The release condition is satisfied when the pipper is placed on the target while simultaneously attempting to achieve a predetermined release altitude, airspeed and dive angle. The basic

difference is that all (not just pipper) pre-determined release conditions are displayed on the HUD, thereby avoiding the need to read several instruments at the same time.

The proper release condition is satisfied when the AC has flown the aircraft in such a manner that he simultaneously aligns:

The altitude marker with the reference altitude index.
The TAS marker with the reference TAS index.
The velocity vector with the reference dive angle indicator.
The pipper with the ground target.

Since the reference scales have a limited window, the AC must know exactly what the release condition is and make the same sort of disciplined approach required by Iron Sight bombing.

The pre-determined release conditions are all entered into the computer by means of the CCP Keyboard.

Ordinarily all inputs could be entered individually, but for ease of mechanization to facilitate display evaluation, the program contains nine pre-set release combinations in table form. All pre-set release conditions are changed by entering only one number into the CCP Keyboard.

The A/G MANUAL release conditions are set by the following table:

CCP KEYBOARD NUMBER	0	1	2	3	4	5	6	7	8
REF PITCH ANGLE DEG	-30	-50	-45	-45	-40	-60	-40	-30	-20
PIPPER DEPRESSION MILS	-201	-174	-199	-160	-182	-141	-151	-192	-215
REF RELEASE ALT FT	4000	5000	5000	5000	5000	6000	5000	5000	4000
REF TAS KNOTS	400	350	350	400	400	350	450	450	450

The computer compares the table value:

REF RELEASE ALT	with actual altitude (above S.L. not above target). If the deviation is greater than $\pm$1000 ft., the altitude marker is pinned at the scale limit.
REF TAS	with actual TAS. If the deviation is greater than $\pm$50 knots, the TAS marker is pinned at the scale limit.

The velocity vector in A/G MANUAL is the airspeed vector. Its vertical displacement is controlled by angle-of-attack (α_T) in mil rad, not units. Its lateral displacement is controlled by side slip.

As may be determined by Figure 11, the proper release dive angle, γ_R, is achieved by aligning the velocity vector with the reference pitch angle.

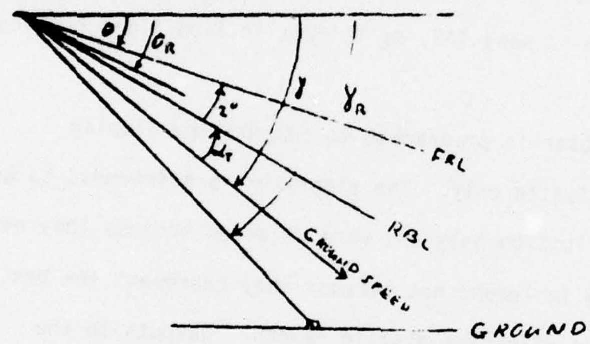


FIGURE 11. A/G MANUAL GEOMETRY

γ = Actual dive angle

γ_R = Proper release dive angle

θ = Actual pitch angle

θ_R = Reference pitch angle from the table

α_T = True angle-of-attack in mil rad referenced from the radar boresight line (RBL).

2^o = Offset angle between the pitch reference Fuselage Reference Line (FRL) and the α_T Ref.

Proper release occurs when:

$$\gamma = \gamma_R$$

$$\theta - 2^o - \alpha_T = \theta_R - 2^0 - \alpha_T$$

This equality is established when the velocity vector is aligned with the pitch reference line since the vertical displacement of the vector velcoity is - $(2^{o} + \alpha_T)$ and the vertical displacement of the dive angle reference line is made to be equal to $(\theta_R - \theta - 2^{o} - \alpha_T)$.

Setting up the table from bombing table information requires a fore knowledge of target altitude above S.L. and of release angle-of-attack in addition to release TAS, as it does in Iron Sight bombing.

XV. A/A MISSILE OPERATION

A. The AUSTERE HUD computer is programmed to compute the display algorithms for one missile only. The algorithms are intended to be used for display evaluation only and were selected because they were reasonably simple to implement not because they represent the best set of algorithms for effective missile launch. Outputs to the missile are not programmed. The display algorithms programmed were developed by Raytheon for ease of implementation on an analog computer and thus their form is somewhat similar to those currently implemented in the F-4E. The rear seat attack display containes the same information, (Rmax, Rmin, ASE, STEERING DOT, RANGE RATE) used in a conventional F-4E attack display. The response of the display to the same attack situation will be different from that in a conventional F-4E.

XVI. A/A GUNNERY OPERATION

Two gunnery modes are implemented in the AUSTERE HUD System; the Honeywell HOTLINE (TRACER) and a Lead Computing mode equivalent to that in the F-4E. The exact characteristics, performance capabilities and limitations, software program listings and the algorithms have not been released to Westinghouse. The program tape delivered by Honeywell is overloaded onto the portion of the program under WEC control, (Executive, I/O, Missiles, Air-to-Ground, and Displays).

The visible response of the display to the inputs into the gunnery programs has been noted at the bench test level using a "static" simulator t[illegible]ply those inputs individually. The correctness of the response is [illegible] more upon intuition than upon a knowledge of the algorithms.

A. TRACER DISPLAY RESPONSE

The display response of the TRACER program to the gunnery routine inputs is given in the following paragraphs.

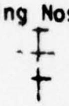
1. Pitch Rate

The tracer line always starts below the gun cross (second bullet, six hundred feet).

Rising Nose

Positive pitch rate causes the line to extend straight down the display. Honeywell limits the line length to 12°, which is produced by a positive pitch rate of +6 deg/sec.

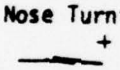
Falling Nose



Negative pitch rate causes the line to extend straight up the display. It reaches the top (and folds out the bottom) with a negative pitch rate of -2.5 deg/sec. Zero pitch rate shrinks the line to zero length, causing the range bars to overlap.

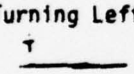
2. Yaw Rate

Nose Turning Right



Positive Yaw Rate causes the line to shift left. The line reaches the edge of the display when yaw rate equals +4 deg/sec.

Nose Turning Left



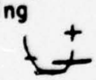
Negative Yaw Rate causes the line to shift right. The line reaches the edge of the display when yaw rate equals -4 deg/sec.

3. Roll Rate

Falling Rht Wing

Positive Roll Rate causes the line to curve counterclockwise. It is limited at 114 deg/sec at which point the TRACER line breaks up and then reverses.

Rising Rht Wing



Negative Roll Rate causes the line to curve clockwise. It exhibits the same phenomena at -114 deg/sec. Tracer line curvature is produced only by a roll rate input.

4. Acceleration

The line lengthens slightly with normal acceleration and shift slightly left/right with lateral acceleration. Longitudinal acceleration probably would not produce a visible response.

5. Angle-of-Attack

A positive angle of attack should lengthen the line.

6. True Air Speed

Changes in TAS produced no visible response.

7. Altitude (Pressure, Density, Mach)

Altitude has no affect on the length of the line, however, the position of the 1000, 2000, 3000 foot range lines does change. As the altitude increases, the range lines move up the display. Honeywell limits altitude to 40K ft, above which the process reverses itself.

8. Range and Range Rate

Range and range rate are not inputs to the TRACER program.

B. ALCOSS

The response of the ALCOSS pipper is generally the same as that of a single point on the TRACER line (at whatever range is being used). It shouldn't necessarily be the exact spot, but close and at least in the same direction. Previous comments on the TRACER response apply also to the noted ALCOSS response. In addition, ALCOSS also responds to range and range rate.

1. Range

Increasing range causes the pipper to drop. Range is limited between 200 and 7000 feet.

2. Range Rate

Closing range rate causes the pipper to rise. Opening rate causes the pipper to drop. Range Rate is limited to 0 $\pm$ 250 ft/sec by the ALCOSS program.

XVII. A/G AUTO ALGORITHMS

A. A/G AUTO AIDED VISUAL BOMBING ALGORITHMS

Assume: a. Zero Ejection Velocity
b. Zero td, time delay from pickle
c. Vacuum Trajectory

1. Compute Ground Speed in x,y,z coordinates from ground speed N,E,V inputs.

$$\begin{bmatrix} V_{gx} \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_{gN} \\ E \\ V \end{bmatrix}$$

$$V_{gx} = V_N \cos\psi + V_E \sin\psi \qquad \text{where}$$

$$V_{gy} = -V_N \sin\psi + V_E \cos\psi \qquad \psi = \text{INS Heading Angle}$$

$$V_{gz} = V_v$$

2. Compute ALTITUDE ABOVE THE TARGET

$H_T = H - h_t$

H = Pressure altitude derived from LnP

h_t = 2300 ft, a constant fixed in the program or selectable via NAV Panel

= ALTITUDE of TARGET ABOVE SEA LEVEL

3. Compute Time of fall, t_f

$$t_f = \frac{-V_v}{g} + \sqrt{\left(\frac{V_v}{g}\right)^2 + \frac{2H_T}{g}} \quad \text{seconds}$$

$g = 32.184$ ft/sec^2

4. Compute Impact Point I_x, I_y, I_3

$$\begin{bmatrix} I_x \\ I_y \\ I_z \end{bmatrix} = \begin{bmatrix} V_{gx}\ t_f \\ V_{gy}\ t_f \\ H_T \end{bmatrix}$$

5. Rotate Impact VECTOR into A/C l,m,n coordinates

$$\begin{bmatrix} I_\ell \\ m \\ n \end{bmatrix} = \begin{bmatrix} \phi \end{bmatrix} \begin{bmatrix} \theta \end{bmatrix} \begin{bmatrix} I_x \\ I_y \\ I_z \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} I_x \\ I_y \\ I_z \end{bmatrix}$$

$$= \begin{bmatrix} \phi \end{bmatrix} \begin{bmatrix} I_x \cos\theta - I \sin\theta \\ I_y \\ I_x \sin\theta + I_z \cos\theta \end{bmatrix}$$

$$
\begin{bmatrix} I_\ell \\ m \\ n \end{bmatrix} = \begin{bmatrix} I_x \cos\theta & I_y\, 0 & -I_z \sin\theta \\ I_x \sin\theta \sin\phi & I_y \cos\phi & I_z \cos\theta \sin\phi \\ I_x \sin\theta \cos\phi & -I_y \sin\phi & I_z \cos\theta \cos\phi \end{bmatrix}
$$

In A/C coordinates, the deflection angles of the pipper are:

$$\gamma = \frac{-I_n}{I_\ell} \times 1000 \quad \text{mrad} \quad \text{depression}$$

$$\zeta = \frac{I_m}{I_\ell} \times 1000 \quad \text{m rad} \quad \text{cross angle}$$

In display centered coordinates (7^o below waterline)

$$I_{\ell 0} = I_x (\cos 7^o \cos\theta + \sin 7^o \sin\theta \cos\phi) - I_y \sin 7^o \sin\phi$$
$$+ I_z(-\cos 7^o \sin\theta + \sin 7^o \cos\theta \cos$$

$$I_{m0} = I_x \sin\theta \sin\phi + I_y \cos\phi + I_z \cos\theta \text{ Sin } \phi$$

$$I_{n0} = I_x (-\sin 7^o \cos\theta + \cos 7^o \sin\theta \cos\phi) - I_y \cos 7^o \sin\phi$$
$$+ I_z(\sin 7^o \sin\theta + \cos 7^o \cos\theta \cos\phi$$

$$X = \frac{I_{m0}}{I_{\ell 0}} \times 1000 \text{ mil rad}$$

$$Y = \frac{I_{n0}}{I_{\ell 0}} \times 1000 \text{ mrad.}$$

If $Y > -93$ mrad. ($\gamma > -215$ mrad)

No bomb fall line

Place pipper at 2^o below gun cross and roll stabilize

$$\gamma = -4^o \cos\phi \qquad \zeta = -4^o \sin\phi$$

B. VACUUM TIME OF FALL DERIVATION

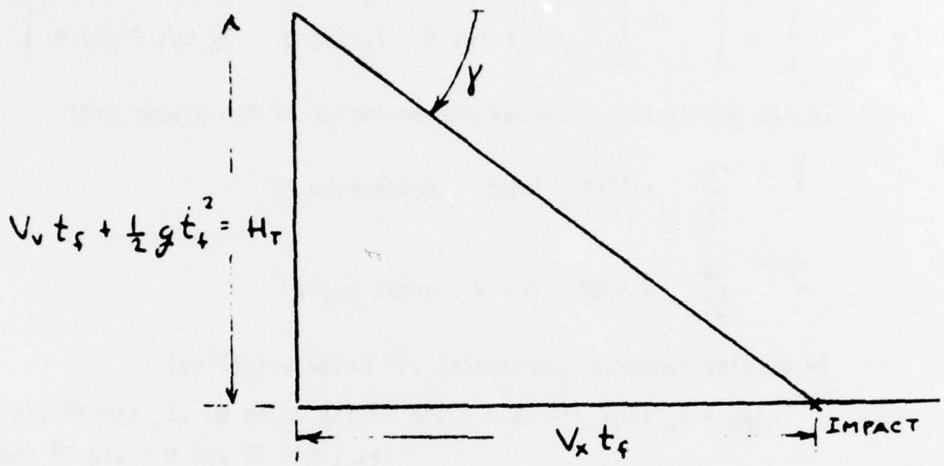


FIGURE 12. A/G AUTO t_f GEOMETRY

1. $+V_v t_f + \frac{1}{2} g t_f^2 = H_T$
2. $+2V_v t_f + g t_f^2 = 2H_T$
3. $2V_v t_f g + g^2 t_f^2 = 2H_t g$
4. $V_v^2 + 2V_v t_f g + g^2 t_f^2 = 2H_t g + V_v^2$
5. $(V_v + t_f g)^2 = 2H_T g + V_v^2$
6. $V_v + t_f g = \quad 2H_T g + V_v^2$
7. $t_f = \frac{-V_v}{g} + \left[\frac{2H_T}{g} + \frac{V_v^2}{g^2}\right]^{\frac{1}{2}}$

XX. A/G AUTO TEST CASE

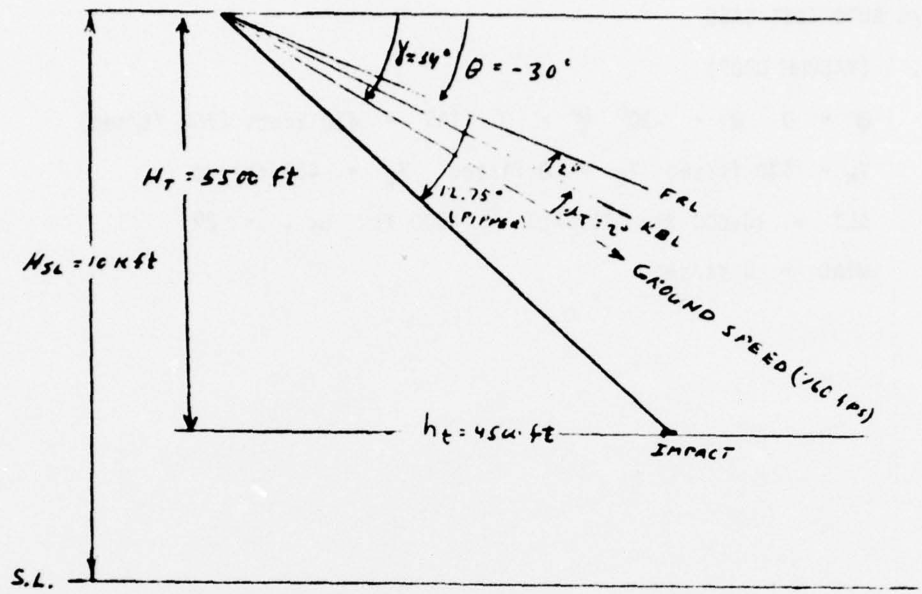
A. (VACUUM DROP)

$\phi = 0$ $\theta = -30^\circ$ $\psi = 0$ TAS = 450 knots (760 ft/sec)

V_N = 630 ft/sec V_E = 0 ft/sec V_V = 425 ft/sec

ALT = 10,000 ft, TGT ALT = 4500 ft $\alpha_T = 2^\circ$

WIND = 0 ft/sec



make;

$$\begin{bmatrix} V_{gx} \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_N \\ V_E \\ V_V \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 630 \text{ ft/sec} \\ 0 \\ 425 \text{ ft/sec} \end{bmatrix}$$

$$\begin{bmatrix} V_{gx} \\ y \\ z \end{bmatrix} = \begin{bmatrix} 630 \\ 0 \\ 425 \end{bmatrix}$$

$$H_T = H - h_T = 10{,}000 - 4500 = 5500 \text{ ft.}$$

$$t_f = \frac{-V_v}{g} + \sqrt{\left(\frac{V_v}{g}\right)^2 + \frac{2H_T}{g}} \quad \text{seconds}$$

$$= -\frac{425}{32.2} + \sqrt{\left(\frac{425}{32.2}\right)^2 + \frac{2(5500)}{32.2}}$$

$$= -13.2 + 22.7$$

$$t_f = 9.5 \text{ sec}$$

$$\begin{bmatrix} I_x \\ y \\ 3 \end{bmatrix} = \begin{bmatrix} V_{gx} & t_f \\ V_{gy} & t_f \\ H_T & \end{bmatrix} = \begin{bmatrix} 630 \times 9.5 \\ 0 \\ 5500 \end{bmatrix} = \begin{bmatrix} 5992.4 \\ 0 \\ 5500 \end{bmatrix}$$

$$\begin{bmatrix} I \\ m \\ n \end{bmatrix} = [\phi][\theta]\begin{bmatrix} I_x \\ I_y \\ I_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix}\begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix}\begin{bmatrix} I_x \\ I_y \\ I_3 \end{bmatrix}$$

$$\begin{bmatrix} I \\ I_m \\ I_n \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} \cos(-30) & 0 & -\sin(-30) \\ 0 & 1 & 0 \\ \sin(-30) & 0 & \cos(-30) \end{bmatrix}\begin{bmatrix} 5992.4 \\ 0 \\ 5500 \end{bmatrix} = \begin{bmatrix} .866 & 0 & .5 \\ 0 & 1 & 0 \\ -.5 & 0 & .866 \end{bmatrix}\begin{bmatrix} 59 \\ \\ 55 \end{bmatrix}$$

$$\begin{bmatrix} I \\ I_m \\ I_n \end{bmatrix} = \begin{bmatrix} 7939.4 \\ 0 \\ 1766.8 \end{bmatrix}$$

Pipper depression angle $-\frac{I_n}{I_\ell} = -\frac{1766.8}{7939.4} \times 1000 = -222.5$ mrad

B. PIPPER DEPRESSION WITH SIMULATED DRAG

The AUSTERE HUD Program uses a multiplier of 0.92 on I_x, therefore the computed depression angle is as follows:

$$\begin{bmatrix} I_\ell \\ I_m \\ I_n \end{bmatrix} = \begin{bmatrix} \varphi \end{bmatrix} \begin{bmatrix} \theta \end{bmatrix} \begin{bmatrix} 0.92 \times 5992.4 \\ 0 \\ 5500 \end{bmatrix} = \begin{bmatrix} .866 & 0 & .5 \\ 0 & 1 & 0 \\ -.5 & 0 & .866 \end{bmatrix} \begin{bmatrix} 5513 \\ 0 \\ 5500 \end{bmatrix}$$

$$\begin{bmatrix} I_\ell \\ m \\ n \end{bmatrix} = \begin{bmatrix} 7524.26 \\ 0 \\ 2006.5 \end{bmatrix}$$

$$\text{Depression Angle} = -\frac{2006.5}{7524.26} \times 1000 = -266.67 \text{ mrad}$$

Velocity Vector

Depression from waterline:

$$\begin{bmatrix} V \\ m \\ n \end{bmatrix} = \begin{bmatrix} \varphi \end{bmatrix} \begin{bmatrix} 0 \end{bmatrix} \begin{bmatrix} V_x \\ y \\ 3 \end{bmatrix} = \begin{bmatrix} \cos(-30) & 0 & -\sin(-30) \\ 0 & 1 & 0 \\ \sin(-30) & 0 & \cos(-30) \end{bmatrix} \begin{bmatrix} 630 \\ 0 \\ 425 \end{bmatrix}$$

$$\begin{bmatrix} V \\ V_m \\ V_n \end{bmatrix} = \begin{bmatrix} .866 & 0 & .5 \\ 0 & 1 & 0 \\ -.5 & 0 & .866 \end{bmatrix} \begin{bmatrix} 630 \\ 0 \\ 425 \end{bmatrix} = \begin{bmatrix} 758 \\ 0 \\ 53 \end{bmatrix}$$

$$V_g \text{ (A/C coord)} = \left[V^2 + V_m^2 + V_n^2 \right]^{\frac{1}{2}} = 759.86 \text{ ft/sec}$$

$$\text{depression} = -\frac{53}{759.86} \times 1000 = -69.75 \text{ mrad} \quad \text{(35 mrad below gun cross)}$$

$$\text{Lateral} = \frac{0}{759.86} \times 1000 = 0 \text{ mrad}$$

XXI. UTILITY ALGORITHM TEST CASES

ALTITUDE, H

$$H = 27{,}592 (n P_s - n P) -2400 (n P_s - n P)^2$$

TEST CASE ALT = 10,000 ft, LnP = 3.024 Ln P_s = 3.399
(Standard Atmospheric Day Tables)

$$H = 27{,}592\ (3.399 - 3.024) - 2400\ (3.399 - 3.024)^2$$

$$H = 10{,}347 - 337.5$$

$H = 10009.5$ ft Table Value = 10,000 ft

AIR DENSITY, ρ

$$\rho = .07647 - .0022399\ \frac{H}{1000} + .0000246707\left(\frac{H}{1000}\right)^2 - .00000011413\left(\frac{H}{1000}\right)^3 \quad \#/ft^3$$

@ 10,000 ft

$$\rho = .07647 - .022399 + .00246707 - .00011413$$

$$\rho = 0.0564239 \quad \#/ft^3$$

$$\rho_{slugs} = 0.0017523 \quad slugs/ft^3$$

$$slug/ft^3 = \frac{\#/ft^3}{g}$$

Table Value = .056475 $\#/ft^3$

= .0017553 $slugs/ft^3$

Mach No, M

For $H \leq 36K$ ft

$$M = \frac{V_a}{1116.9 - 4H}$$

H in K ft

V_a = TAS (ft/sec)

For $H > 36K$ ft

$$M = \frac{V_a}{972}$$

For H = 10K ft and V_a = 760 ft/sec

$$M = \frac{760}{1116.9 - 4(10)} = 0.706$$

$M = 0.706$ Table Value = .705

SIDE SLIP, β

$$\beta = \frac{228{,}571\ A_m}{(\rho\ slugs/ft^3)V_a^2} \quad \text{mrad}$$

$Am = +0.1g$

$V_a = 760\ ft/sec^2$

ρ_{slugs} = 0.0017523

$$\beta = \frac{228{,}571 \times 0.1}{(.0017523)(760)^2} = \frac{22857.1}{1012.1285}$$

$$\beta = 22.58 \text{ mrad}$$

XXII. I/O SIGNAL LIST

This section describes the characteristics of the analog inputs and outputs of the AUSTERE HUD computer.

STEADY STATE OUTPUT SIGNALS

SYMBOL	QUANTITY	WORD	FORMAT	VOLTAGE	NOMINAL AMPLIFIER a_1	b_1	SCALE FACTOR a_2	b_2	POLARITY	
	RETICLE X	0	164000	0 to 5V	-0.5	+2.5	50.22 milli-radians/volt	0	+RIGHT	12 bits LSB
	RETICLE Y	1	164001	0 to 5V	-0.5	+2.5	50.22 milli-radians/volt	0	+UP	12 bits LSB
SE_{AZ}	AZIMUTH COMPONENT OF STEERING ERROR	2	164002	$\pm$4.9V	-0.976	0	3.5V/in	0	+RIGHT	(9LSB)
SE_{EL}	ELEVATION COMPONENT OF STEERING ERROR			$\pm$4.9V	-0.976	0	3.5V/in	0	+UP	(9MSB)
ASE	ALLOWABLE STEERING ERROR	3	164003	+0.35 to +4.2V	-0.384	2.272V	3.5V/in		+	(9LSB)
R_A	AERODYNAMIC RANGE	4	164004	0 to 6.26V	-0.635	3.175V	0.1494V/6000 ft.,.0249mv/ft.		+	(9MSB)
R_{MIN}	MINIMUM LAUNCH RANGE			0 to 1.26V	-0.1235	0.6375V	0.1494V/6000 ft.,0.249mv/ft.	0	+	(9LSB)
CAZ-CMD	COMPUTER AZIMUTH COMMAND	5	164005	$\pm$10V	-2.00	0	0.416V/DEG	0	+PORT	(9LSB)
CEL-CMD	COMPUTER ELEVATION COMMAND			$\pm$21V	-4.22	0	0.416V/DEG	0	+DOWN	(9MSB)
$V_{C_{GAP}}$ *	RANGE RATE GAP	7	164007	+1.35V to -12.00V	+1.33148	-5.259V	-4V/900	0		12 bits LSB

*V_CX1 270° = 2700 KNOTS CLOSING V_CX3 270° = 900 KNOTS CLOSING   -V = CLOSING

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OSCILLATORY INPUT SIGNALS

SYMBOL	QUANTITY	WORD	SELECT FORMAT	VOLTAGE/FREQUENCY	AMPLIFIER/HALF-CYCLE INTEGRATOR GAIN	OFFSET	PHASE ANGLES ax	ay	POLARITY with ØC	
θ_x^*, θ_y	PITCH ANGLE	0	165440	$11.8 \pm 0.25V_{RMS}$ @400 Hz	0.243Vdc/Vpeak 0.3436Vdc/Vrms	0.0			Nose Up	$\theta_{x-z}=11.8\sin(\theta+60)$ $\theta_{y-z}=11.8\sin(\theta+120)$
ϕ_x^*, ϕ_y	ROLL ANGLE	1	165441	$11.8 \pm 0.25V_{RMS}$ @400 Hz	0.243Vdc/Vpeak 0.3436Vdc/Vrms	0.0			Right Wing Down	$\phi_{x-z}=-11.8\sin(\phi+60)$ $\phi_{y-z}=-11.8\sin(\phi+120)$
$-SIN\lambda_s^*$		2	165442	18 Vrms @ 400 Hz Max	0.162Vdc/vpeak 0.229Vdc/Vrms	0.0			Antenna Left	18(-sinλs)
$COS\lambda_s$									Always In Phase	18 (cosλs)
ψ_x^*, ψ_y	HEADING ANGLE	3	165443	$11.8 \pm 0.25V_{RMS}$ @400 Hz	0.243Vdc/Vpeak 0.3436Vdc/Vrms	0.0			East (0=True North)	$\psi_{x-z}=-11.8\sin(\psi-120)$ $\psi_{x-z}=-11.8\sin(\psi-60)$
$SIN\lambda_e^*$		4	165444	18Vrms @ 400 Hz Max	0.162Vdc/Vpeak 0.229 Vdc/Vrms	0.0			Antenna Up	18 sin λe)
$-COS\lambda_e$									Always Out of Phase	18(-cosλe)
α_T^*	ANGLE OF ATTACK	5	165445	6.48Vrms@400 Hz .36 Vrms/Deg	0.422Vdc/Vpeak 0.5968Vdc/Vrms	0.0			Nose Above Vel.Vec.	
REF18	18-VOLT AC REF.400Hz PHASE C			18.00Vrms@400 Hz	0.158Vdc/Vpeak	0.0			Phase C Ref.For All AC	
$\dot{\theta}^*$	PITCH RATE	6	165446	1.5Vrms @400 Hz 0.28V/deg/s	1.91Vdc/Vpeak	0.0			Rising Nose	
$\dot{\phi}$	ROLL RATE			1.5Vrms @400Hz 0.28Vdeg/s	1.91Vdc/Vpeak	0.0			Falling Rgt.Wng.	
A_N^*	LATERAL ACCELERATION	7	165447	0.8Vrms/G±1GMax	3.57Vdc/Vpeak	0.0			+G(Out Rgt.Wng.)	
$\dot{\psi}$	YAW RATE			1.5Vrms@400 Hz 0.28V/deg/s	0.191Vdc/Vpeak	0.0			Nose Turning Right	
A_N^*	NORMAL ACCELERATION	8	165450	3.0 Vrms to15Vrms 2.4Vrms/g	0.196Vdc/Vpeak	0.0			Positive Down	

*This conversion inputted as:

Discrete Input Word 1, using Select Format 163021

Change #1
Change #4

STEADY-STATE INPUT SIGNALS

SYMBOL	QUANTITY NAME	WORD NUMBER	SELECT FORMAT	SCALE FACTORS				RANGE	
				SENSOR		NOM. AMP.			
				a_1	b_1	a_2	b_2		
A_N	NORMAL ACCELERATION	0	165420	35644 V/G	1.671 V	-1.91	4.775 V	-2G to +8.5G 0 to +5Vdc	+G is down
$\dot{\theta}_I$	PITCH RATE	1	165421	1.2055 V/DEG/S	2.505 V	-1.91	4.775 V	-30°/s to +30°/s 0 to +5Vdc	+Rate = Rising Nose
A_N	LATERAL ACCELERATION	2	165422	1.2055 V/G	2.523 V	-1.91	4.775 V	-2G to+2G, 0 to +5VDC -200°/S to +200°/S	+G Out Right Wing
$\dot{\phi}_I$	ROLL RATE	3	165423	.0121 V/DEG/S	2.454 V	-1.91	4.775 V	0 to 5Vdc	+G = Falling Right Wing
V_a	TRUE AIR SPEED	4	165424	3.95 mv/fps	0	-0.976	4.88 V	0 to 2531.7 fps 0 to 10 VDC	
ℓnPs	LN OF STATIC AIR PRESSURE	5	165425	2.9115 v/LN Units	0	-0.976	4.88 V	0 to 3.43459 LN Units 0 to 10 VDC	
TR	STADIAMETRIC RANGE	6	165426	0.575 mv/ft	0	-2.8	4.844 V	0 to 6000 Ft. 0 to +3.45V	
$\dot{R}$	RANGE RATE	7	165427	6.667 mv/fps	0	-0.2891	-3.904 V	3.3756 to (-) 30.38 VDC	$-V_{IN}$ = CLOSING
W_j	ANTENNA ANGULAR RATE ELEVATION	8	165430	(-)0.5 V/DEG/S	0	-0.3016	0	$\overline{\ }$30°/S to +30°/S +15 to (-) 15 VDC	$+V_{IN}$ = UP TO DOWN (NEG. RATE)
W_k	ANTENNA ANGULAR RATE AZIMUTH	9	165431	(-)0.5 V/DEG/S	0	-0.3016	0	-30°/S to +30°/S +15 to (-) 15 VDC	$+V_{IN}$ = RIGHT TO LEFT (NEG. RATE)
V_v	VERTICAL VELOCITY	10	165432	0.01 V/fps	0	-0.477	0	(-)10 to +10 VDC (-)1000 to +1000 fps	+fps = UP

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STEADY-STATE INPUT SIGNALS (Continued)

SYMBOL	QUANTITY NAME	WORD NUMBER	SELECT FORMAT	SCALE FACTORS SENSOR a_1	b_1	NOM. AMP. a_2	b_2	RANGE	
V_E	VELOCITY EAST	11	165433	6.667 mv/fps	0	-0.239	0	(-)20 to +20 VDC (-)3000 to +3000 fps	+fps = EAST
E_{SAA}	SERVO AZ. ANGULAR ERROR SIG.	11	165433	6.25 V/Deg.		-0.453		(-)1.5° to +1.5° (-)9.37 to +9.37 VDC	A + signal indicates that antenna must be driven port
$\dot{\psi}$	YAW ANGULAR RATE	12	165434	82.666 mv/Deg/S	2.508 V	-1.91	4.775 V	(-)30°/S to +30°/S 0 to +5VDC	+Rate causes +Angle A/C Turning Right
V_N	VELOCITY NORTH	13	165435	6.667 mv/fps	0	-0.239	0	(-)20 to +20 VDC (-)3000 to +3000 fps	+fps = NORTH
E_{SEA}	SERVO EL. ANGULAR ERROR SIG.	13	165435	6.25 V/Deg.		-0.453	0	(-)1.5° to +1.5° (-)9.37 to +9.37 VDC	A + signal indicates that antenna must be driven down
A_L	LONGITUDINAL ACCELERATION	14	165436	1.299 V/G	2.466 V	-1.91	4.775 V	(-)2G to +2G 0 to +5 VDC	+G Accel = Aft to Fwd.
R	RADAR	15	165436	0.6667 mv/ft	0	-0.955	4.775 V	0V to 10VDC 0 to 15,000 FT.	RDRAA Missile Mode
R	RANGE	15	165436	0.333 mv/ft	0	-.0955	4.775 V	0V to 100VDC 0 to 150,000 FT.	RDRA/E Missile Mode

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SECTION 5

F-4E AUSTERE/HUD PROGRAM, RADAR MODIFICATION, PHASE D

Amendment No. 2, Exhibit A P00003

Technical Report
to
Flight Test Analysis

16 September 1975

WESTINGHOUSE ELECTRIC CORPORATION
Post Office Box 746
Baltimore, Maryland 21203

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

This Austere HUD/Gunsight Program is a multiphase program dealing with improvements to the Air Force F-4E operational inventory aircraft. Phase A was concerned with improving the pilot's display and improving the gunnery modes, as well as establishing Air Force Systems Engineering Avionic Facilities (SEAFAC), as well as an F-4E Fire Control Simulator hot mockup. Phases B and C deal with air combat evaluation modes and sensor coordination modes planned in the future, and Phase D deals with APQ-120 radar improvements which is the subject of this report.

The motivation for conducting Phase D (radar improvements) stems from Air Force COMBAT SAGE reports prepared by PACAF, which state that the altitude line causes both target acquisition problems and radar target breaklocks. This condition is considered a deficiency in the F-4E, APQ-120 radar. In addition, it has been recommended in COMBAT SAGE and the F-4E Advanced Avionics TAC ROC 1272 that the time required to accomplish automatic radar acquisition on an enemy target be instantaneous in order to meet the tactical requirements of air combat. The conclusions of the CONSTANT HIT study program strongly support the above findings and recommend immediate APQ-120 hardware changes.

This report concerns itself with the Phase D efforts which implemented new hardware for the acquisition altitude breaklock problem, description of such new hardware, a flight test program of such new hardware, an analysis and evaluation of the flight test data results, and conclusions and recommendations as a result of the flight test.

This report is to provide the F-4 SPO with the necessary data to ascertain the risk assessment mechanization, performance, and operational suitability for incorporating improvements as an ECP to the operational F-4E/APQ-120 radar. In addition to this report, a USAF (Air Force Flight Test Center) report was prepared on the flight test evaluation and results.

The hardware mechanizations for the mentioned radar improvements have been flight verified and proven by performance data included in this report and in a separate classified section retained at AFAL. Substantial improvements to the altitude line/acquisition problem result from these hardware improvements. In addition, the hardware that was flown was designed to represent, as close as possible, the production configuration of the hardware changes.

In the pursuit of this Phase D project, the Air Force SEAFAC facilities at Wright-Patterson Air Force Base were utilized in the software area (F-4E FCS simulator hot mockup), the Air Force A/C 304 instrumentation facilities operated by McDonnell-Douglas Aircraft were utilized, and the Air Force Flight Test Center, F-4E Flight Operations, conducted the tests. The Nellis Air Force Base Aggressor Squadron evaluated the improvements, and Hill Air Force Base and Westinghouse Spares/Supplies/Depot facilities were used. The US Navy facility at Pt. Mugu, California assisted by the loan of a spare computer console/memory loader during peak requirements periods.

2. SUMMARY AND CONCLUSIONS

As a result of adding the improved feedhorn and the digital automatic acquisition circuitry in the APQ-120, the following benefits were realized over the present operational configuration:

a. Radar lock and track through the altitude line over land was improved to 95 percent.

b. Radar lock and track through the altitude line over water was improved from 10 to 70 percent.

c. Automatic radar acquisition through the altitude line over land was improved from 50 to 100 percent.

d. Automatic radar acquisition through the altitude line over water was improved from 0 to 95 percent.

e. The noise quality as seen on the display was improved, thereby increasing target detection capability. This allows the APQ-120 to better discriminate and lock-on to an airborne target in the presence of ground return.

f. The tactical utility of the Fire Control System was substantially improved by decreasing automatic target acquisition on boresight from 6-1/2 seconds to less than 1/2 second.

g. An additional automatic acquisition growth option is available in elevation scan or sector scan in addition to the boresight mode by programming the antenna in the automatic acquisition mode.

2.1 FLIGHT TEST HIGHLIGHTS

- There were 49 flights associated with the Phase D program.
- Total flight hours amounted to 70.3 hours on two F-4E aircraft.
- Altitude line data points accumulated were 323 points.
- Maximum range points accumulated were 106 points.
- Acquisition points were 1491.
- Clutter run points were 17.
- Total data points accumulated were 1937.
- Complete analog instrumentation postrecordings were obtained for each flight.
- Digital in-flight recordings were made.
- Radar video recordings were made for the first time for the AN/APQ-120 for altitude line evaluations.
- Air Force Flight Test Center ground analysis (ADAGAST) magnetic tapes were prepared without manual data preparation.
- The Phase D effort was conducted over the 5-month period of April through August 1975.
- The flight test finished approximately 2 weeks early.
- Comprehensive flight test briefings/debriefings were pursued and outstanding Air Force management was evidenced at all levels of the program.
- A thorough Class II Modification Configuration Control procedure was carried through by the Air Force and Westinghouse.
- Outstanding cooperation between US Air Force divisions, contractors, and US Air Force bases led to the early completion and success of the program.
- There were no GFE computer and support hardware failures at any time during this program.
- There were no new equipment radar failures experienced.
- In the midst of flight tests, A/C 304 developed (6/30/75) an engine failure. A/C 0368 was used by exchanging the Fire Control System with A/C 304 and continuing the radar evaluation tests. The engine of A/C 304 was then changed. Upon completion of the engine change, A/C 304 was placed back into service. This resourcefulness by AF management contributed immensely to the success of this program.

3. PROGRAM OBJECTIVES

The objective of the program was to verify though flight test a solution to theF-4E, APQ-120 radar altitude/acquisition breaklock problem. The objective included fabricating and testing a hardware configuration that is as close as possible to the final APQ-120 ECP, verification of its performance under actual flight profiles utilizing target aircraft, determination of pilot usability and acceptability, and an evaluation of the solution by a Tactical Air Command Aggressor Squadron from Nellis Air Force Base. The final objective of the program was the development of data and reporting of the results to the F-4 SPO for their consideration of a potential ECP.

3.1 THE APPROACH

The approch was to modify the APQ-120 radar in aircraft 304 at the Air Force Flight Test Center; modify as required, the hardware and software developed on Phase A of this program, perform a flight test to provide the risk assessment data to the F-4 SPO concerning the engineering parameters and operational suitability of this new hardware solution, and to acquire USAF usability/acceptability confirmation.

The collection and analysis of engineering data was accomplished by using an analog instrumentation pod, an on-board digital data instrumentation system, and a radar video instrumentation unit. Analysis was accomplished by the Air Force and Westinghouse at the Air Force Flight Test Center and at Westinghouse-Baltimore. The assessment of pilot usability and acceptability was accomplished by the USAF F-4E Flight Test Team at the Air Force Flight Test Center. A set of data, based on thorough evaluation criteria, was generated by the Air Force Flight Test Center Flight Test Team.

3.1.1 Radar Changes - Antenna

The APQ-120 radar was modified to incorporate a modified feedhorn providing a reduction in the far sidelobe level. A GFE antenna was modified by installing a newly built feedhorn and suppressor plate and running the original antenna configuration and new configuration through an antenna range at Westinghouse in Baltimore. Data was gathered on both configurations during the flight test phase of this program.

This change was made to provide improved acquisition and tracking capability through a reduction in the altitude line return to the system. In conjunction with other changes, this change will reduce the percentage of times the system will acquire the altitude line rather than a target and it will also reduce the percentage of times the system will breaklock or transfer to the altitude line.

3.1.2 Radar Changes - LRU 20 and LRU 21

A GFE synchronizer and the LRU 20 was modified to provide circuitry for automatic digital target acquisition and pulsewidth target discrimination during acquisition and tracking (see figures 3-1 through 3-5).

The Digital Automatic Acquisition (DAA) circuits added to the system employ a detection criteria whereby a number of contiguous range cells are rapidly examined by digital techniques for the presence of a target. When a target is detected, the DAA circuitry prepositions the synchronizer tracking gate to the proper range. This action is followed by "normal" synchronizer lock-on and track operation. Utilizing the DAA circuits to preposition the synchronizer acquisition/tracking gate to the target is significantly faster than the sweeping range gate technique employed by the analog automatic acquisition circuits. The above changes provide the following advantages:

- Pulsewidth discrimination, which reduces the attempts at altitude line acquisition
- Altitude line rejection if an acquisition on it is attempted by the DAA circuits.

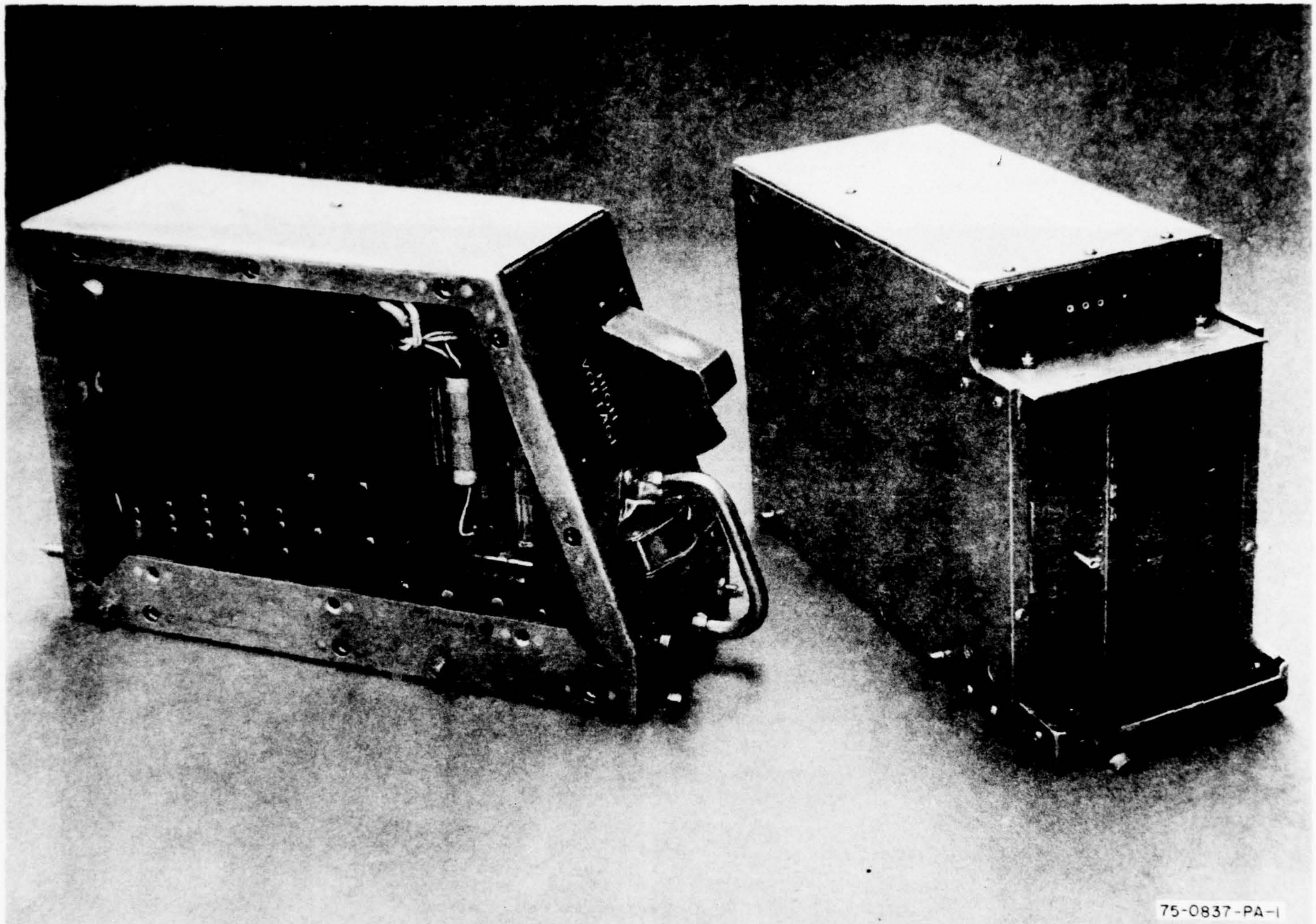


Figure 3-1. LRU 20 - Modified and Old Configuration

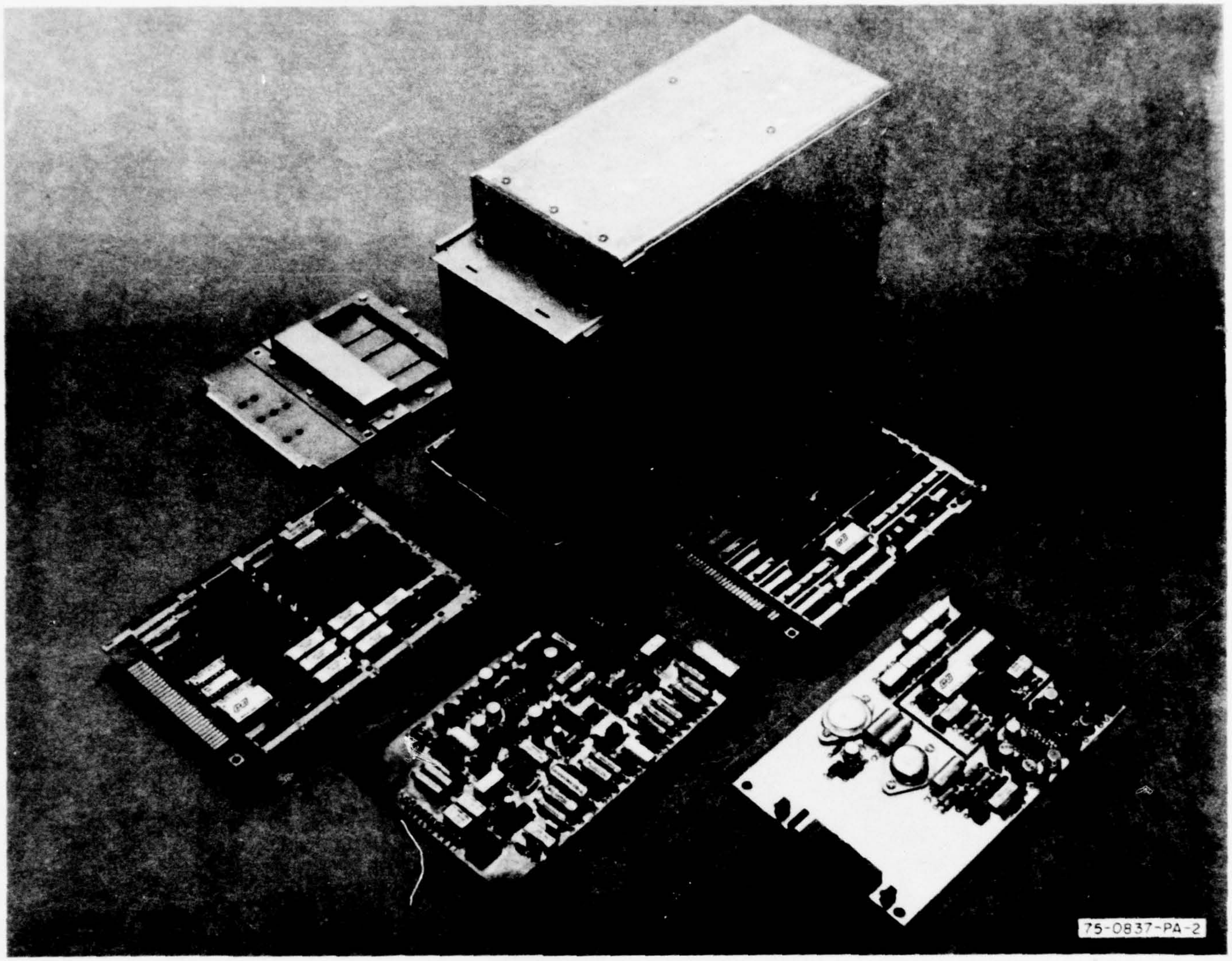


Figure 3-2. Breakdown of New Digital Auto Acquisition Unit

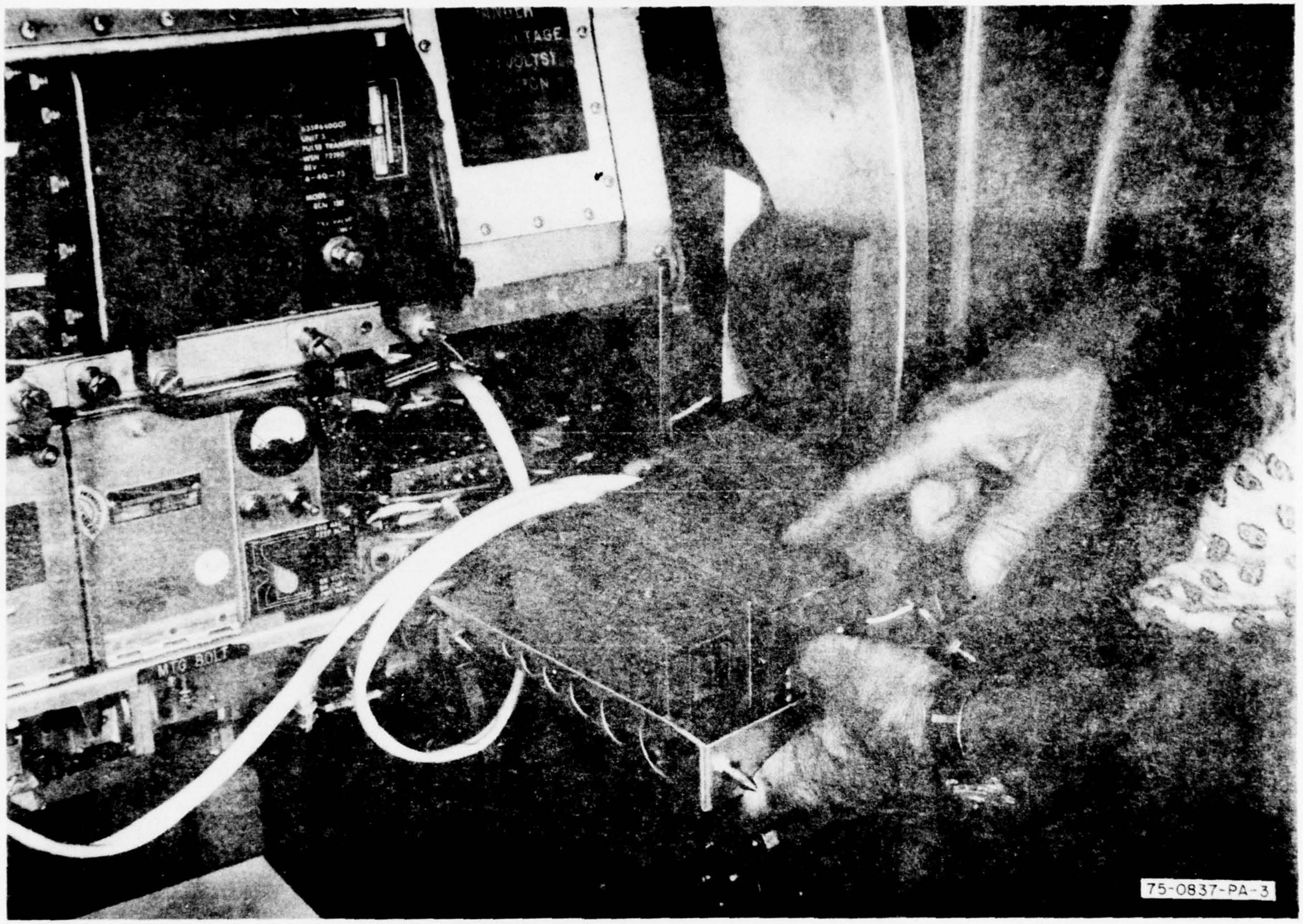


Figure 3-3. New -600V Power Supply Mounted in Pulse Stalo, LRU 21

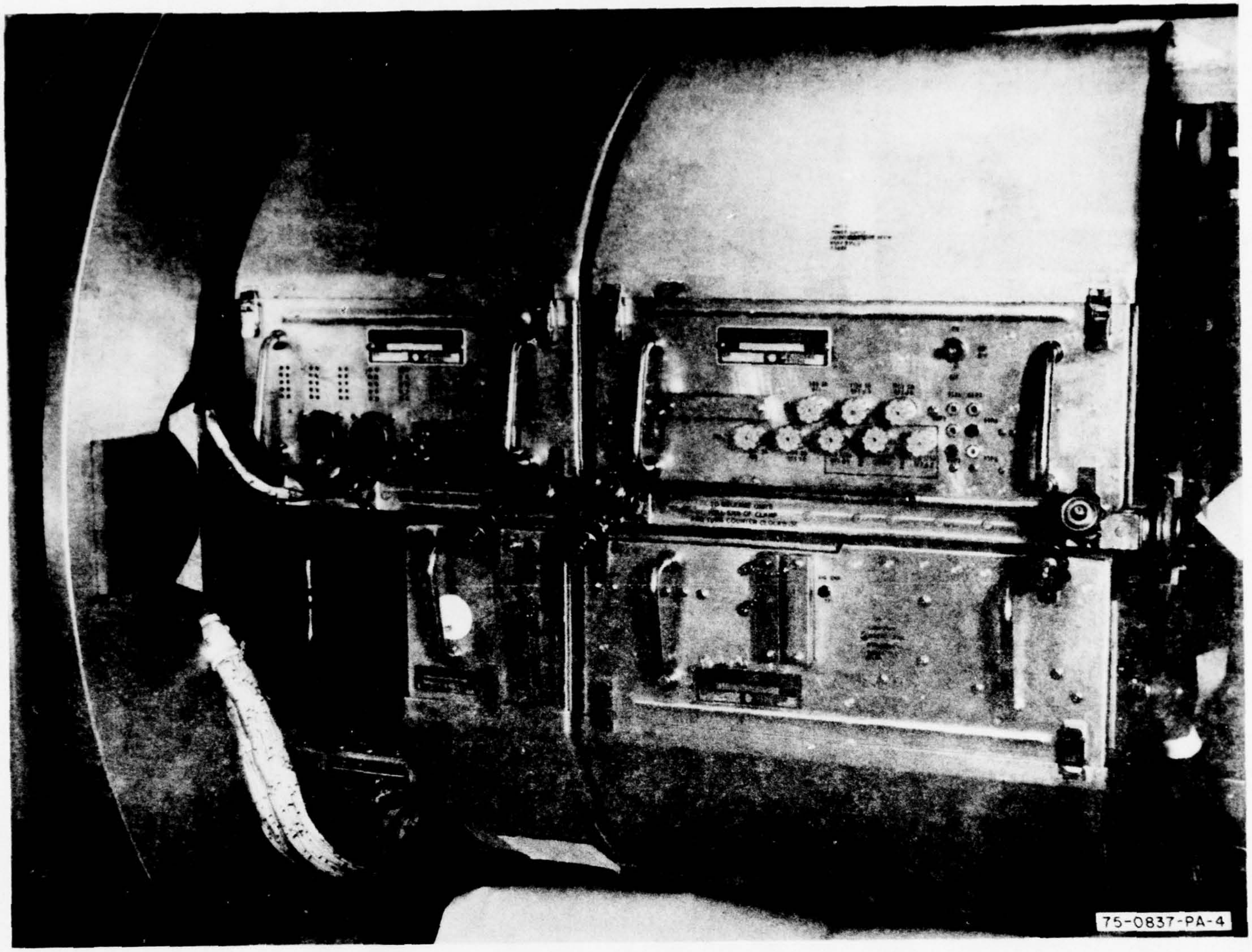


Figure 3-4. Mounting Location of New LRU 20 Digital Auto Acquisition Unit

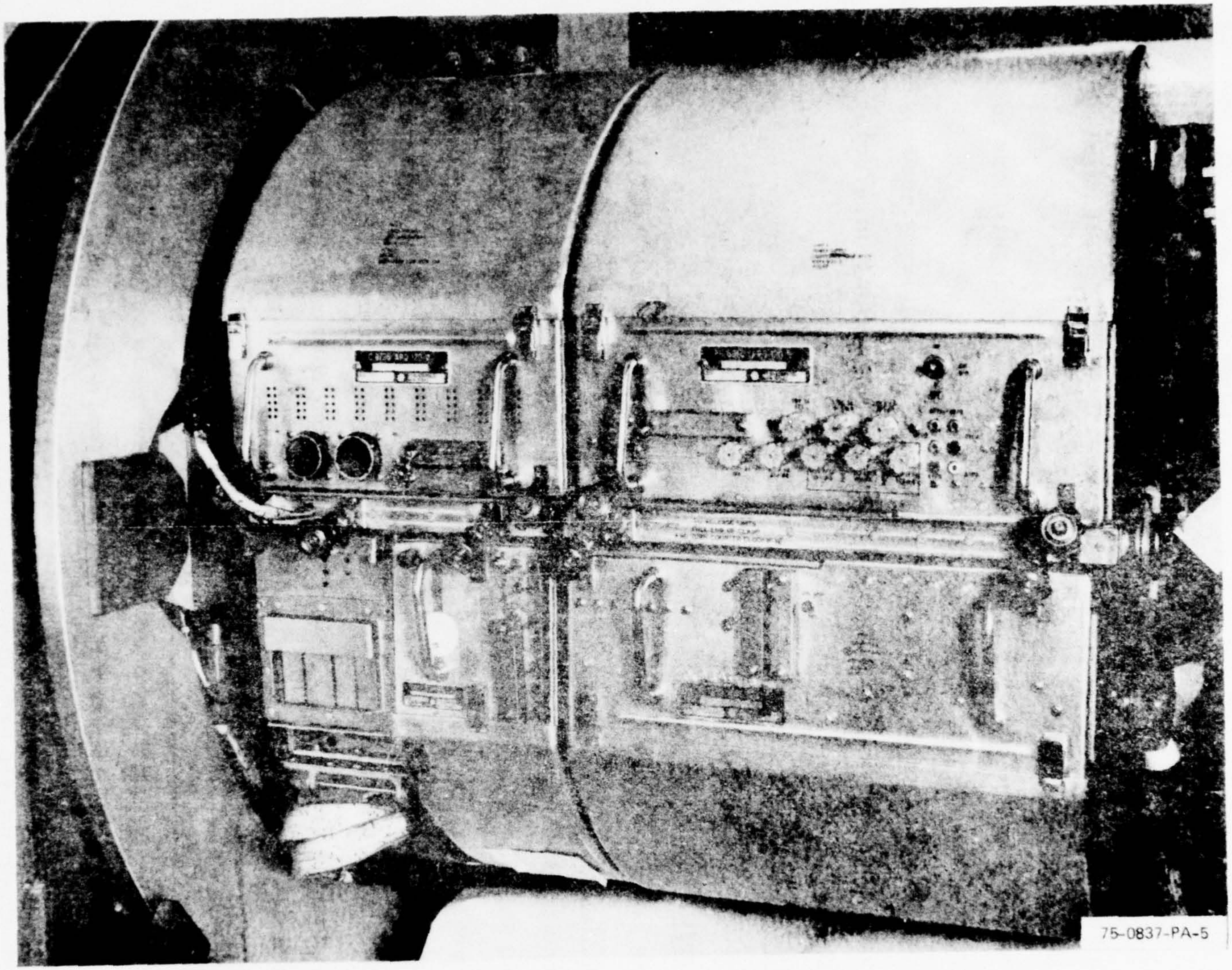


Figure 3-5. New LRU 20 Digital Auto Acquisition Mounted in Radar Nose Package

The rapid acquisition capability provided by DAA eases the operational problem of obtaining any acquisition because:

a. It minimizes the duration of time during which the targets have to be spotlighted in acquisition from boresight.

b. It provides a growth potential by opening up the angular window in which acquisition can be obtained because it makes acquisition from a scan mode possible.

3.1.3 Radar Interconnect Changes

See Class II Modification, paragraph 3.2 of this report.

3.1.4 Aircraft Wiring Changes

Paragraph 3.2 covers the Class II Modification Change Order (MCO).

3.1.5 AN/AYK-8 Changes

Drive circuitry to control the antenna from the computer was added from GFE supplied Standard Electronic Modules (SEM) of the AN/AYK-8 system. In addition, angle tracking loop error signals were provided to the computer again from GFE modules. The net result was that by changing the Phase A software, the ability to command the antenna by the computer was provided. In addition, through software the ability to transition from a command to a tracking mode was provided by changing switches on the general control panel installed in Phase A (GFE B-57G Navigation Panel).

3.1.6 F-4E Fire Control System Simulator Changes

Necessary changes on the hot bench mockup were made at the Air Force Flight Test Center to permit ground testing of software and testing of computer hardware changes. The static simulator was modified to accommodate antenna servo error signals and antenna scan pattern control signals (Az and El), and computer dominant mode to servo unit. plus inputs of automatic acquisition initiate and stop scan signal.

3.1.7 ACE Software Changes

Changes for the software for ACE were planned and made. The routine will not be made available from Honeywell until Phases B and C of this overall program.

3.1.8 Instrumentation Changes

Paragraph 3.10.1 summarizes the additional analog instrumentation signals made available by McDonnell-Douglas in the instrumentation pod. The digital recorder of Phase A was used, but a change in format of recorded data was necessitated by the Air Force Flight Test Center ground program requirements, and the change of recorded data. In addition a Sony TV recorder was added to record video from the radar along with synchronizer circuit signals.

3.2 CLASS II MODIFICATION KIT

Westinghouse prepared the necessary documentation and analysis for AFFTC personnel to perform a Class II modification of: installation, calibration, and ground checkout on A/C 304. In addition, Westinghouse provided necessary assistance to AFFTC personnel during the installation. No external or structural modifications were required. The modifications were accomplished in less than 2 weeks during April 1975.

To incorporate the new automatic acquisition (auto-acq) capability into the APQ-120 radar for purposes of evaluation and with minimal required change to aircraft and system wiring, the following changes were made:

a. The Power Supply, PP-4847/APQ-120(V) (LRU 20), was replaced with a new chassis containing the digital auto-acq circuitry mounted on two digital and two analog printed circuit board assemblies. All input power and signals were provided by means of a cable from the test connector of Electrical Synchronizer SN-484/APQ-120(V) (LRU 17) to a like connector on Digital Auto-Acq Chassis (LRU 20).

b. The -600-volt power supply presently located in LRU 20 was redesigned to accommodate the latest (ECN 40 solid-state LNA) configuration of Waveguide Assembly CG-3775/APQ-120(V) (LRU 19), whereas only the supply voltage for the klystron local oscillator is required. This new power supply was mounted on the chassis of Radio Frequency Oscillator O-1430A/APQ-120 (LRU 21), cabled between existing connectors 20P1 and 19P5.

c. To preclude any wiring changes in Electrical Equipment Rack MT-4613/APQ-120(V) (LRU 15), unused CORDS and ASPECT wiring in the Radar Set Control C-8908/APQ-120(D), Antenna Control C-9466/APQ-120(V), and Electrical Synchronizer SN-484/APQ-120(V) was modified to supply switching logic and signal flow for the following newly mechanized functions:

(1) Automatic acquisition excitation in 9-mile range without boresight interlock.

(2) Slaved automatic acquisition mode in 9-mile range - this mode will have an approximate 9-mile automatic acquisition range sweep with computer command of antenna (elevation scan, azimuth boresight).

(3) Lock-on capability in beacon mode (beacon was not available for test).

(4) Normal automatic acquisition in boresight, 5 miles or 9 miles.

d. In addition, azimuth and elevation error signal outputs were provided for future use of auxiliary equipment systems. The 7A7 PWA of the Antenna Control C-9466/APQ-120(V) (LRU 7) was modified by installation of output driver circuits. Wiring normally used for ±5 degree E_s signals was utilized to provide these outputs.

e. One wire each in the Pulse Transmitter T-1269/APQ-120(V) (LRU 5) and Control Oscillator C-9465/APQ-120(V) (LRU 18) was disconnected to prevent CORDS mode of operation in these LRU's.

A copy of the Class II Modification Kit follows including an updated A/C wiring list at the APQ-120 computer interface. Also included as Appendix A12 is the engineering data that contributed to generating the Class II Modification Kit.

CLASS II MODIFICATION CHANGE ORDER (MCO)

CLASS II MODIFICATION CHANGE ORDER (MCO)	ACFT MDS	ACFT SERIAL NO	MODIFICATION NUMBER	CHANGE LETTER
	F 4E	68-0304	M-4-0-031Z	

JOB ORDER NUMBER	DATE REQUIRED

MATERIAL REQUIREMENTS	YES	NO
MUST BE ORDERED		X
REWORK EXISTING		X
FABRICATE		X
FURNISHED	X	

ATTACHED DATA	YES	NO	DRAWINGS EFFECTED
ELECTRICAL ANALYSIS		X	None
PNEUMATIC ANALYSIS		X	
HYDRAULIC ANALYSIS		X	
OPERATING INSTRUCTIONS		X	
MAINTENANCE INSPECTION INSTRUCT		X	
STRESS ANALYSIS		X	DATA LIST ATTACHED: X

MODIFICATION ENGINEER	ORGANIZATION OR OFFICE SYMBOL	DUTY PHONE NUMBER	DATE SUBMITTED
S. Slocum	DOTFM	7-2031	1 May 1975

DESCRIPTION OF MODIFICATION CHANGE

Installation of circuitry in the radar lockon sequence, which will give the Aircraft Commander the ability of instant automatic acquisition (within .3 seconds) of any target within a range of 8.86 miles. Additional features of this mechanization are:

1. Rapid reaction of digital control.
2. Complete control of the radar antenna by digital computer.
3. Vertical scan antenna during acquisition.

See detailed description attached.

APPROVAL

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
PROJECT MANAGER E. T. Meschko, Capt.	[signature]	3 Jun 75
K. W. Erotnov, L/Col.	[signature]	3 Jun 75
CCB CHAIRMAN		

MAINTENANCE

MHR ESTIMATES (Hours/Days)	DAYS DOWN TIME

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
QUALITY CONTROL REVIEW		
CHANGES FORWARDED		
INSTRUMENTATION INSTR RCV'D		
AIRCRAFT SCHEDULED		
INSTALLATION STARTED		
INSTALLATION COMPLETED		

COST INFORMATION

IN CMPNT	OP MAT CMPNT	MAINT MANHOURS	DESIGN MANHOURS	TOTAL
$	$	$ -	$	$

MAINTENANCE CERTIFICATION (Records Updated)

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
ACFT HIST FILE		
AFTO FORM 21		
AFTO FORM 95		
TO FILE		
WEIGHT AND BALANCE		

FINAL CERTIFICATION

PRINT OR TYPE NAME AND GRADE	SIGNATURE	DATE
PROJECT MANAGER		
MODIFICATION ENGINEER		
SAFETY		
OPERATIONS		
QUALITY CONTROL		
CHIEF OF MAINTENANCE		

AFFTC [illegible] 9

DATA LIST

Austere [illegible]
Class II [illegible]. No. [illegible]-0317
Change Order [illegible]
F 4E [illegible] Ser. No. [illegible]-0304

DWG SIZE	CODE IDENT	DOCUMENT IDENTIFICATION NO	REV	DOCUMENT NOMENCLATURE
B	97942	SK - CB 51975	A	APQ 120 Digital Auto-Acq Modifica[illegible] Wiring Sketch.
B	97942	9RD 5075X1		Digital Auto-Acq Cable, W1 Wiring Diagram.
B	97942	9RD 5075		Digital Auto-Acq Interconnect Dia[illegible]
B	97942	9RD 507[illegible]		Digital Auto-Acq Error Detector
B	97942	9RD 5077		Digital Auto-Acq Digital Board #1
B	97942	9RD 5078		Digital Auto-Acq Analog Board
B	97942	9RD 5079		Digital Auto-Acq Digital Board #2

AF FORM 1659 DEC 61 REPLACES AF FORM 1302, DEC 57, WHICH IS OBSOLETE

LIST OF MATERIALS

ITEM	QTY	DESCRIPTION	STOCK NO. / [illegible]
1.	(1)	Electrical Synchronizer, SN-[illegible]/APQ 120(V)	[illegible]
2.	(1)	Digital Auto-Acq Chassis (Modified LRU 20)	N/A
3.	(1)	(-) 600 Volt Power Supply with Input/Output Cables W2 & W3	N/A
4.	(1)	Digital Auto-Acq Cable Assembly, W1	N/A

WEIGHT AND BALANCE DATA REPORTING

1. ACFT MODEL	2. SERIAL NUMBER	3. DATE
F 4E	68-0304	3 June 1975

INSTRUCTIONS: Submit weight and balance data on changes, alterations, modifications to the ... and support items of standard ... installation.

4. STANDARD EQUIPMENT: X INSTALLED X REMOVED RELOCATED

5. MODIFICATION: INITIAL INSTALLATION COMPLETE REMOVAL X MODIFICATION CHANGE

7. GROUP B COMPONENT REMOVED: TEMPORARY PERMANENT 8. GROUP A PARTS: INSTALLED ... M-4-D-0317 (C)

ITEM NUMBER	LOCATION COMPARTMENT	EQUIPMENT NOMENCLATURE	CODE	WEIGHT	MOMENT ARM
1.	Radar	Electrical Synchronizer, SN-484/APQ 120(V)	R	12.5	
	Radar	Electrical Synchronizer, SN-484/APQ 120(V)	A	12.5	
2.	Radar	Power Supply, PP-4847/APQ 120(V)	R	9.3	
	Radar	Power Supply, PP-4847/APQ 120(V)	A	7.5	
3.	Radar	Digital Auto-Acq Cable Assembly, W1	A	.5	
4.	Radar	Radio Frequency Oscillator, O-1430A/APQ 120	R	4.4	
	Radar	Radio Frequency Oscillator, O-1430A/APQ 120	A	5.1	

CERTIFICATION OF CHANGE

9. SIGNATURE OF PERSON ACCOMPLISHING CHANGE	10. ORGN SYMBOL	11. DY PHONE NO.	12. DATE	13. SIGNATURE OF ...

[1] Horizontal, Lateral, Vertical Moment Arm is required ...

ANALYSES

Weight and Balance - Nil

Electrical - No Change

Hydraulic - Not Applicable

Pneudraulic - Not Applicable

Stress - Not Applicable

Inspection/Maintenance - No Change

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-031Z (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
1.	Open radome and extend AN/APQ 120 radar package per applicable T. O.				
2.	Remove AN/APQ 120 LRU's per the following (10) steps and applicable T. O. Remanded to the custody of DOTFM contractor for disposition.				
3.	Pulse Transmitter, T-1269/APQ 120(V) (LRU 5) for modification.				
4.	Power Supply, PP-6992/APQ 120(V) (LRU 6) for modification.				
5.	Antenna Control, C-9466/APQ 120(V) (LRU 7) for modification.				
6.	Set Control, C-8908/APQ 120(D) (LRU 9) for modification.				
7.	Forward Intra Target Data Indicator, P/N F33615-73-C-1292 (LRU 12) for custody.				
8.	Electrical Synchronizer, SN-484/APQ 120(V) (LRU 17) for custody.				

AFFTC FORM JUL 70 8D PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-031Z (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	Q C INSPECTOR
9.	Control Oscillator, C-9465/APQ 120(V) (LRU 18) for modification.				
10.	Waveguide Assembly, CG-3775/APQ 120 (V) (LRU 19) for modification.				
11.	Power Supply, PP-4847/APQ 120(V), (LRU 20) for replacement/custody.				
12.	Radio Frequency Oscillator, O-1430A/APQ 120 (LRU 21) for modification.				
13.	Modification of AN/ APQ 120 radar LRU's shall be accomplished by the DOTFM contractor (W) per the (32) steps following.				
14.	Pulse Transmitter, T-1269/APQ 120(V) (LRU 5) - Remove pin/wire from 5P1/H, identify, insulate and tieback.				
15.	Power Supply, PP-6992/APQ 120(V), (LRU 6) - Install transient suppression resistors in + 250v regulators per (W) RN AZ 844. (2) steps following.				
16.	Install resistor R27 (M22684/01-0068) on pwa 6A% per (W) RN # AZ 844.				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-0312 (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
17.	Install resistor R20 (M22684/01-0068) on pwa 6A4 per (W) RN # AZ 844.				
18.	Antenna Control, C-9466/APQ 120(V) (LRU 7) - Modify per the following (7) steps.				
19.	Remove pin/wire from 7J3/41, identify, insulate and tie back.				
20.	Install new pin/wire at 7J3/41, route and connect terminal end at 7TB1/79.				
21.	Install diode between 7TB1/72 and 7TB179 per Dwg. No. SK CB51795(A). Cathode at 7TB1/79.				
22.	Disconnect lead at 7TB1/29, re-connect at 7TB1/72.				
23.	Add a jumper between 7TB1/29 and 7TB1/79.				
24.	Remove pin/wire from 7J1/9, identify insulate and tie back.				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-0312 (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
25.	Move wire from 7A18/26 to 7A18/49. in addition to wire presently on 7A18/49.				
	Note: This concludes modification of Antenna Control, C-9466/APQ 12(V) (LRU 7) pertinent to Computer Dominant, Stop Scan, and Boresight signals.				
26.	Radar Set Control, C-8908/APQ 120(D) (LRU 9) - Modify per the following (9) steps.				
27.	Remove pin/wire from 9J1/F, identify insulate, and tie back.				
28.	Install new pin/wire at 9J1/F, to the plate end of 9CR28 on relay shelf of LRU 9.				
29.	Remove pins/wires at 9J1/n and 9J2/v; identify, insulate and tie back.				
30.	Install a jumper between 9J1/n and 9J2/v.				
31.	Remove diode 9CR13 per Dwg. No. SK CB51795(A).				
32.	Add jumper from Range Switch 9S7/B2/8 to MODe Switch 9S6/C2/6 per Dwg. No. SK CB 51795(A).				

AFFTC FORM JUL 70 8B PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-031Z (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
33.	Move wire from Mode Switch 9S6/A1/5 to 9S6/C2/5 per Dwg. No. CB51795(A).				
34.	Move wire from Mode Switch 9S6/A1/4 to 9S6/A2/2 per SK CB51795(A).				
35.	Move wire from Aspect Switch 9S9/A2/1 to the junction of 9CR90 & 9CR98 per SK CB51795(A).				
	Note: Steps 27 through 35 concludes modification of the Radar Set Control, C-8909/APQ 120(V) (LRU 9) pertinent to Beacon lockon, 10 mile Auto-Acq, Stop Scan, and Computer Dominant signals.				
36.	Electrical Synchronizer, SN-484/APQ 120(V) (LRU 17) - Modification has been previously incorporated at DOTFM contractor facility - complete replacement.				
37.	Control Oscillator, C-9465/APQ 120(V) (LRU 18) - Remove pin/wire from 18J2/20 identify, insulate and tie back.				
38.	Waveguide Assembly, CG-3775/APQ 120 (V) (LRU 19) - Modification consists of installation of solid-state Low Noise Amplifier per applicable T. O.				
39.	Leave LNA connector 19P5 disconnected, identify, insulate and tie back.				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-0312 (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
40.	Power Supply, PP-4847/APQ 120(V), (LRU 20) - Modification has been incorporated at DOTFM contractor's facility - Complete LRU replacement.				
41.	Radio Frequency Oscillator, O-1430A/APQ 120 (LRU 21) - Modification per the following (4) steps.				
42.	Remove the 'hat' section 514R123001, with 21A3, Beacon Oscillator Multi.				
43.	Remove Beacon Oscill. Multi, 21A3; install on contractor furnished 'hat' section.				
44.	Install contractor furnished (-) 600 volt power supply on new 'hat' section.				
45.	Install new 'hat' section on Radio Frequency Oscillator, O-1430A/APQ 120 (LRU 21).				
	Note: Steps 42 through 45 complete modification of Radio Frequency Oscillator, O-1430A/ APQ 120 and the (-) 600 volt power supply. Steps 14 through 45 complete modification of all AN/APQ 120 LRU's.				
46.	Modification of Electrical Equipment Rack, MT-4613/APQ 120(V) (LRU 15) - Modification consists of re-routing new (-) 600 volt power supply cables per the following (7) steps.				

AFFTC FORM JUL 70 8B PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-031Z (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	QC INSPECTOR
47.	Install Radio Frequency Oscillator, 1430A/APQ 120 (LRU 21) with (-) 600 volt power supply attached.				
48.	Route pre-wired (-) 600 volt Input Cable, W2 into vacant cavity of the Electrical Equipment Rack, MT-4613/APQ 12(V)(LRU 15) to rear of Pulse Trancmitter.				
49.	Route Cable Assembly, W2 straight across Equipment Rack to the port side, into area to rear of LRU 20.				
50.	Detach "rack and panel" connector 20J1 from Electrical Equipment Rack and mate with 20P1 termination of (-) 600 volt Input Cable, W2.				
51.	Route pre-wired (-) 600 volt Output Cable, W3 into vacant cavity of the Electrical Equipment Rack, MT-4613/APQ 12(V) (LRU 15) to rear of Pulse Transmitter.				
52.	Route Cable Assembly, W3 downward, exiting the Equipment Rack in the port, forward area of 19P1.				
53.	Tie wrap all cable runs of the last (5) steps, mate Waveguide Assembly (LRU 19) connector 19J5 with 19P5 termination of (-) 600 volt Output Cable Assembly, W3.				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	PROJ DIRECT NR	DATE WORK STARTED	DATE WORK COMPLETED
F 4E	68-0304	7-3021		

PROJ ENGINEER/PLANNER	PHONE NR	MODIFICATION NR	
S. Slocum	7-2031	M-4-D-031Z (C)	MIL-P-27733 (USAF) will apply to all Modification work.

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR	Q C INSPECT
	Note: Steps 47 through 53 conclude modification of the Electrical Equipment Rack, MT-4613/APQ 120(V) (LRU 15). The Radar system may be restored to original configuration by removal of the (-) 600volt power supply, remounting of connector 20J1, reinstallation of Power Supply, PP-4847/APQ 120 (LRU 20), and reconnection of 20P2 and 19J5.				
54.	Reinstall all remaining AN/APQ 120 LRU's that were removed, steps (3) through (12) per applicable T. O.				
55.	Install Digital Auto-Acq Cable, W1; 17P4 terminal at Electrical Synch, SN-484/APQ 120(V) (LRU 17), 20P2 termination at Digi-Auto-Acq Chassis (LRU 20).				
56.	Connect Special Instrumentation cable harness at contractor furnished 17J3 on Electrical Synchronizer, SN-484/APQ 120(V).				
57.	Mark and identify all pertinent LRU/hardware with appropriate AFFTC decals.				
58.	Inspect all work areas for quality and integrity of workmanship and components.				
59.	Perform all necessary correlation alignments per T. O. Stow radar package and close radome per T. O.				
60.	DOTFM perform Operational check.				

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AIRCRAFT MODIFICATION WORKSHEET

ACFT TYPE	ACFT SERIAL NR	[illegible]
F 4E	68-0304	7-[illegible]

PROJ ENGINEER/PLANNER	PHONE NR	[illegible]	
S. Slocum	7-2031	M-4-D-031Z (C)	[illegible] to all [illegible]

SYM	DESCRIPTION OF WORK ACCOMPLISHED	MANHOURS EXPENDED	WORK COMPLETED BY	SUPERVISOR

AFFTC FORM JUL 70 88 PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

SKETCH SHEET
WESTINGHOUSE FORM

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J1

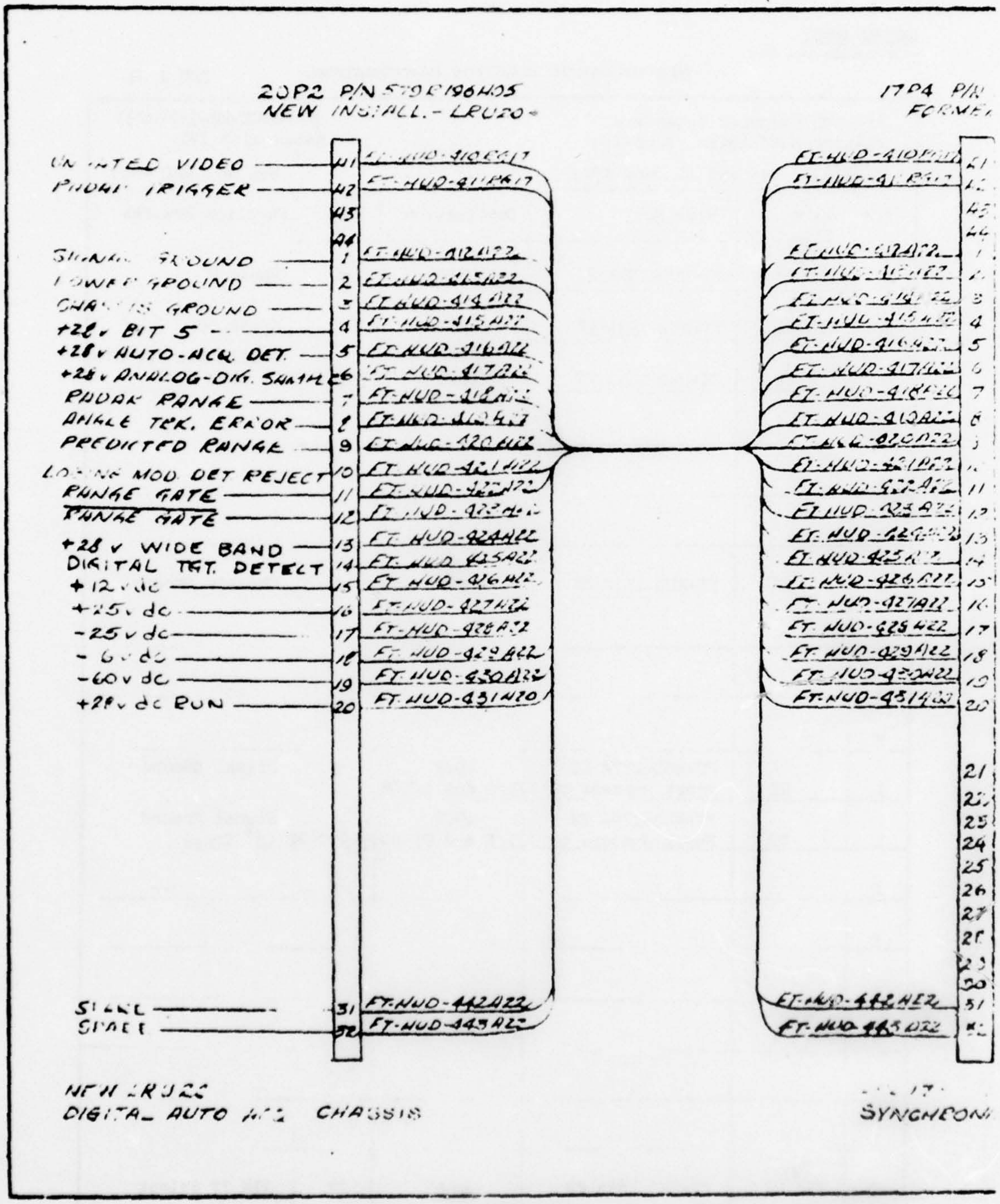
APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

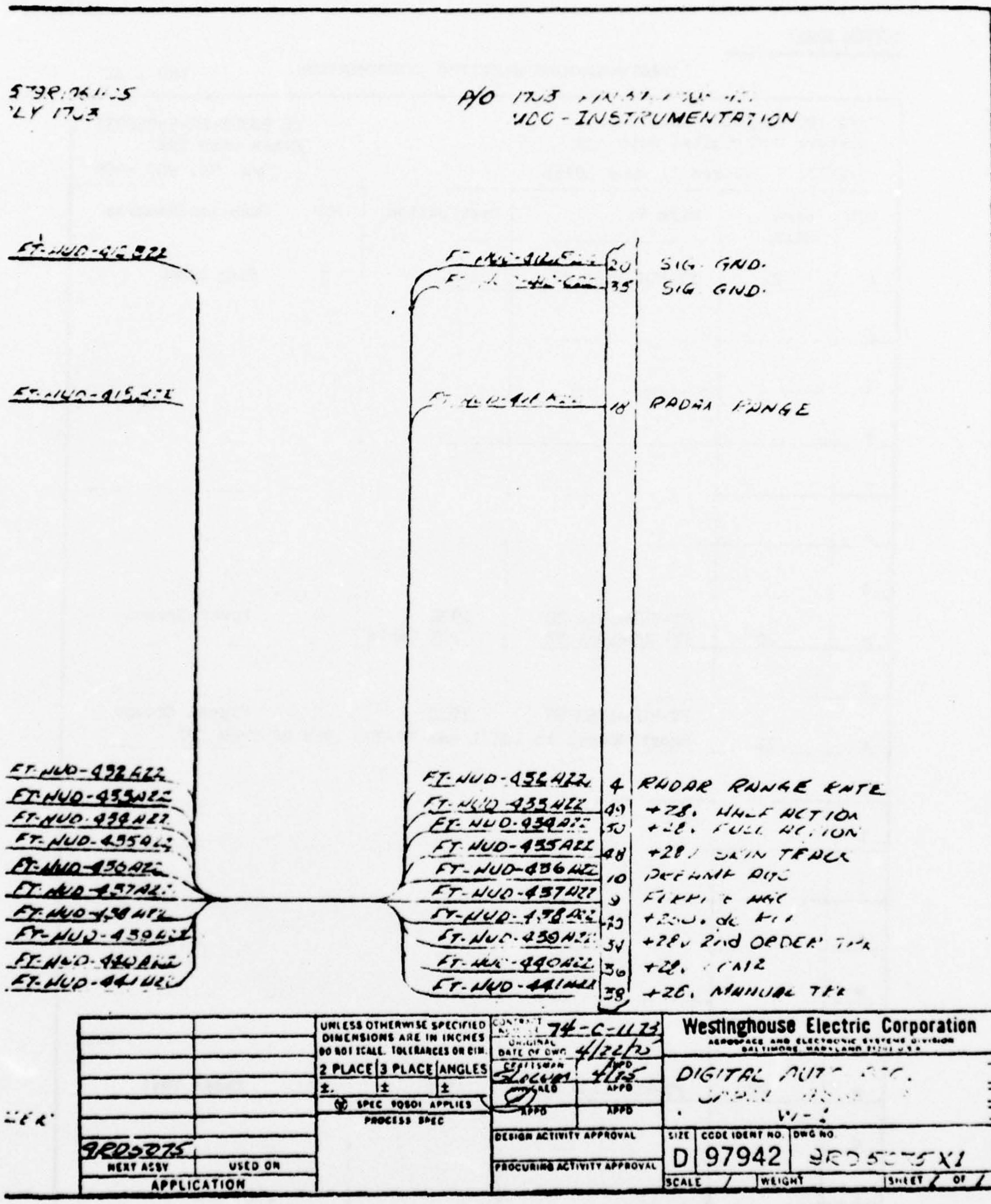
JT POORE-22-55P(003)
Mates with 1P1
Dwg. No. 9RD 4699

	PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
*	A	(1) TPS 22	FT-HUD-192A 22	19J2	K	Spare 9
*	B	(1) TPS 22	FT-HUD-193A 22	19J2	L	Spare 10
	C	22	FT-HUD-194A 22	19J2	M	Shield tie for TPS (10) thru (17)
	D					
	E					
	F					
	G	22	FT-HUD 175A 22	19J2	G	Chassis Ground
	H					
	J					
	K					
	L	22	FT-HUD-177A 22 Short jumpers to 1J1/G and 1J1/M	19J2	g	Signal Ground
	M	22	FT-HUD-178A 22 Short Jumpers to 1J1/L and FT-HUD-195C 22 (6" long)	19J2	v	Signal Ground
	N					
	P					
	R					
	S					
	T					
	U					
	V	(2) TPS 22	FT-HUD-185A 22	19J2	FF	AIM 7F Select
*	W	(3) TPS 22	FT-HUD-187A 22	19J2	k	Break X

SLS - EAFB - 6/11/75

* All shields to 1J2 pin G with FT-HUD-199A 22


20P2 P/N 579E196H05
NEW INSTALL. - LRU20
+28v BIT 5
+28v AUTO-ACQ. DET.
RADAR RANGE
PREDICTED RANGE
RANGE GATE
+28 v WIDE BAND
DIGITAL TGT. DETECT
+12 v dc
+25 v dc
-25 v dc
-60 v dc
FT-HUD-442A22
FT-HUD-443A22
DIGITAL AUTO ACQ CHASSIS



VDC - INSTRUMENTATION
SIG GND.
SIG GND.
RADAR RANGE
RADAR RANGE RATE
+28v 2nd ORDER
Westinghouse Electric Corporation
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DO NOT SCALE. TOLERANCES ON DIM.
2 PLACE
3 PLACE
ANGLES
SPEC 90501 APPLIES
PROCESS SPEC
DESIGN ACTIVITY APPROVAL
PROCURING ACTIVITY APPROVAL
9RD5075
NEXT ASSY
USED ON
APPLICATION
DIGITAL
SIZE
D
CODE IDENT NO.
97942
DWG NO.
SCALE
WEIGHT
SHEET

SKETCH SHEET
WESTINGHOUSE FORM

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J1

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55P(003)
Mates with 1P1
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
X	22	FT-HUD 183A 22	19J2	K	Stop Scan
Y					
Z					
a					
b					
c					
d					
e	22	FT-HUD-191A 22 FT-HUD-196A 22	19J2 1J3 Cable	N	Power Ground
f					
g	22	FT-HUD-176A 22 Short Jumper to 1J1/L and FT-HUD 196B 22 from 1J2	19J2	f	Signal Ground
h					
i					
j					
k					
m					
n					
p	22	FT-HUD-179A 22	19J2	w	Radar Test
q					
r					
s					

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SKETCH SHEET
WESTINGHOUSE FORM 56440

WESTINGHOUSE ELECTRIC CORPORATION LRU 1 J1

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55P(003)
Mates with 1P1
Dwg. No. 9RD 4699

	PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
	t					
	u					
	v					
	w					
	x					
	y					
	z					
	AA					
	BB					CCM
*	CC	(4) TPS 22	FT-HUD-189A 22	19J2	R	V_c x 3
	DD	22	FT-HUD-182A 22	19J2	h	BST
	EE	22	FT-HUD-184A 22	19J2	S	Range Lock
	FF					VI
	GG	22	FT-HUD-181A 22	19J2	i	A/G, Radar
	HH					
	**	(2) TPS 22	FT-HUD-186A 22	19J2	y	AIM 7F Sel. Ret.
	**	(3) TPS 22	FT-HUD-188A 22	19J2	j	Break X Return
	**	(4) TPS 22	FT-HUD-190A 22	19J2	P	V_c x 3 Return
	**	Join the above numbered wires to FT-HUD-195C 22 (6" long) from 1J1/M				

* Shield to 1J2 pin G, wire Number FT-HUD-199A 22
** Join above numbered wires to FT-HUD-195C 22 (6" long) from 1J1 pin M.

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SKETCH SHEET
WESTINGHOUSE FORM [illegible]

WESTINGHOUSE ELECTRIC CORPORATION LRU 1 J2

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55S(003)
Mates with 1P2
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
A					
B					
C					
D					
E					
F					
G	22	FT-HUD-198A 22 FT-HUD-199A 22	19J2 1J1	c	Shield tie Shields tie
H	(11) TPS 22	FT-HUD-161A 22	19J2	p	Dot Azimuth
J	(10) TPS 22	FT-HUD-159A 22	19J2	r	Dot Elevation
K	(14) TPS 22	FT-HUD-167A 22	19J2	t	Vc Gap
L	(12) TPS 22	FT-HUD-163A 22	19J2	s	R Min
M	(15) TPS 22	FT-HUD-169A 22	19J2	HH	R_a
N					
P					
R					
S					
U	(16) TPS 22	FT-HUD- 172A 22	19J2	m	Az. Excit. Return
T					
V					
W					

These shields to pin G

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WESTINGHOUSE FORM 54440

WESTINGHOUSE ELECTRIC CORPORATION LRU 1 J2

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55S(003)
Mates with 1P2
Dwg. No. 9RD 4699

	PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
	X	22	FT-HUD-183A 22	19J2	T	Stop Scan
	Y	(17) TPS 22	FT-HUD-173A 22	19J2	u	El. Excitation
	Z					
	a					
	b					
*	c	(3) TPS 22	FT-HUD-145A 22	19J2	C	Az. Rate
*	d	(4) TPS 22	FT-HUD-147A 22	19J2	D	El. Rate
	e	(10) TPS 22	FT-HUD-140A 22	19J1	Y	Az. Error
	f	(8) TPS 22	FT-HUD-134A 22	19J1	K	El. Error
	g	(13) TPS 22	FT-HUD-165A 22	19J2	AA	ASE
	h	(7) TPS 22	FT-HUD-154A 22	19J2	V	Cos λa
	i	(6) TPS 22	FT-HUD-151A 22	19J2	F	-Sin λa
	j					
	k					
	m	(9) TPS 22	FT-HUD-137A 22	19J1	J	ComDQM
	n					
	p					
	q					
	r					
*	s	(5) TPS 22	FT-HUD-149A 22 c	9J2	E	CWI BIT

All shields to pin C except *

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SKETCH SHEET
WESTINGHOUSE FORM 5444D

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J2

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55S(003)
Mates with 1P2
Dwg. No. 9RD 4699

	PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
	t	22	FT-HUD-143A 22	1J2	v	Range Rate (jumper wire)
*	u	(1) TPS 22	FT-HUD-141A 22	19J2	A	Range
*	v	(2) TPS 22	FT-HUD-143A 22 FT-HUD-143B 22	19J2 1J2	B t	Range Rate Range Rate jumper
	w	22	FT-HUD-180A 22	19J2	x	28v Auto-Acq
	x	(9) TPS 22	FT-HUD-158A 22	19J2	J	$-\cos\lambda e$
	y	(8) TPS 22	FT-HUD-155A 22	19J2	H	$\sin\lambda e$
	z	(8)(9) TPS 22	FT-HUD-156A 22 FT-HUD-157A 22	19J2 19J2	d e	Buffer Ground ($\sin\lambda e$ & $\cos\lambda e$)
	AA	(16) TPS 22	FT-HUD-171A 22	19J2	z	Az. Excitation
	BB					
	CC					
	DD	(17) TPS 22	FT-HUD-174A 22	19J2	EE	El. Excitation Ret.
	EE	(6) (7) TPS 22	FT-HUD-152A 22 FT-HUD-153A 22	19J2 19J2	b U	Buffer Ground ($-\sin\lambda a$ & $\cos\lambda a$)
	FF					
	GG					
	HH					
**		(9) TPS 22	FT-HUD-138A 22	(Terminal ends tied back near those of it's mate FT-HUD-137A 22)		

Note: All shields to pin G except *

** Unused

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SKETCH SHEET

WESTINGHOUSE FORM 8440

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J2

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq

JT POORE-22-55S(003)
Mates with 1P2

3/25/71 (Revised 11 June 1975)

Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
**	(1) TPS 22	FT-HUD-142A 22	19J2	W	Range Return
**	(2) TPS 22	FT-HUD-144A 22	"	X	Range Rate Ret.
**	(3) TPS 22	FT-HUD-146A 22	"	Y	Az. Rate Return
**	(4) TPS 22	FT-HUD-148A 22	"	Z	El. Rate Return
**	(5) TPS 22	FT-HUD-150A 22	"	a	CWI BIT Return
**	(10) TPS 22	FT-HUD-160A 22	"	q	Dot El. Return
**	(11) TPS 22	FT-HUD-162A 22	"	n	Dot Az. Return
**	(12) TPS 22	FT-HUD-164A 22	"	CC	Rmin Return
**	(13) TPS 22	FT- HUD-166A 22	"	BB	ASE Return
**	(14) TPS 22	FT-HUD- 168A 22	"	DD	V_c Gap Return
**	(15) TPS 22	FT-HUD-170A 22	"	GG	R_a Return
**	(16) TPS 22	FT-HUD-172A 22	"	m	Az. Excit. Ret.
**	(17) TPS 22	FT-HUD-174A 22	"	EE	El. Excit. Ret.
**	Join the above wire numbers to FT-HUD-195A 22 & FT-HUD-195B 22				
	(About 18" long each) which connects to 1J1 & 1J3.				
**	(10) TPS 22	FT-HUD-139A 22	19J1	c	Az. Error Return
**	(8) TPS 22	FT-HUD-135A 22	19J1	d	El. Error Return

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SKETCH SHEET

WESTINGHOUSE FORM

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J3

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55SA(003)
Mates with 1P3
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
A	(1) TTS 22	(Brown) FT-HUD-101A 22	19J1	W	α Excitation
B	(1) TTS 22	(Red) FT-HUD-102A 22	19J1	J	α Return
C	(1) TTS 22	(Orange) FT-HUD-103A 22	19J1	V	α_T
E	(2) TTS 22	(Brown) FT-HUD-104A 22	19J1	S	LnPs
D					
F					
G	All Shields	FT-HUD-197A 22	19J1	G	Shield Tie
H	(7) TPS 22	(Brown) FT-HUD-131A 22	19J1	M	Spare 6
J	(7) TPS 22	(Red) FT-HUD-132A 22	19J1	L	Spare 7
K	22	FT-HUD-136A 22	19J1	B	Shield tie from 19J1 TTS (1)(2)(3)
L					
M					
N					
P					
R					
S					
T					
U					
V					
W	(2) TTS 22	(Red) FT-HUD-105A 22	19J1	T	LnPs Excitation

All shields to pin G

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SKETCH SHEET

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J3

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55SA(003)
Mates with 1P3
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
X					
Y	(3) TTS 22	FT-HUD-107A 22	19J1	P	TAS Excitation
Z	(2)(3) TTS 22	FT-HUD-106A 22 FT-HUD-109A 22	19J1 19J1	h g	LnPs Return TAS Return
a					
b					
c					
d					
e					
f					
g					
h					
i	(5) TPS 22	FT-HUD-124A 22	19J1	q	AIM 7F Sense & Switch after boost
j	(1) TPS 22	FT-HUD-112A 22	19J1	U	Eng. Bias Az.
k	(2) TPS 22	FT-HUD-114A 22	19J1	k	Eng. Bias El.
m	(3) TPS 22	FT-HUD-116A 22	19J1	A	Head Aim Az. & Rng. at Launch
n	(4) TPS 22	FT-HUD-118A 22	19J1	t	Head Aim El. & TAS at Launch
p					
q					
r	22	FT-HUD-130A 22	19J1	p	Hold Altitude
s	22	FT-HUD-133A 22	19J1	H	In Range (SHOOT)

All shields to pin G.

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SKETCH SHEET
WESTINGHOUSE FORM

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J3

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55SA(003)
Mates with 1P3
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
t					
u					
v					
w					
x					
y	22	FT-HUD-128A 22	19J1	m	Altitude #1
z	22	FT-HUD-129A 22	19J1	n	Altitude #2
AA	22	FT-HUD-110A 22	19J1	D	Missile Ground
BB	(6) TPS 22	FT-HUD-126A 22	19J1	e	Sparrow Select
CC	22	FT-HUD-123A 22	19J1	b	Port Forward
DD	22	FT-HUD-121A 22	19J1	a	Starboard Forward
EE	22	FT-HUD-122A 22	19J1	F	Port Aft
FF	22	FT-HUD-120A 22	19J1	E	Starboard Aft
GG	22	FT-HUD-111A 22	19J1	Z	Missile Ground
HH					

All shields to pin G.

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SKETCH SHEET
WESTINGHOUSE FORM

WESTINGHOUSE ELECTRIC CORPORATION

LRU 1 J3

APQ 120 Computer Interface
Austere HUD/Digital Auto-Acq
3/25/71 (Revised 11 June 1975)

JT POORE-22-55SA(003)
Mates with 1P3
Dwg. No. 9RD 4699

PIN	Wire Size	Wire No.	Destination	PIN	Function/Remarks
*	(1) TPS 22	FT-HUD-113A 22	19J1	i	Eng. Bias Az. Ret.
*	(2) TPS 22	FT-HUD-115A 22	19J1	s	Eng. Bias El. Ret.
*	(3) TPS 22	FT-HUD-117A 22	19J1	X	Head Aim Az. & Rng. at Launch Ret
*	(4) TPS 22	FT-HUD-119A 22	19J1	r	Head Aim El. & TAS at Launch Ret.
*	(5) TPS 22	FT-HUD-125A 22	19J1	f	AIM 7F Sense & Sw. after boost Ret
*	22	FT-HUD-195A 22	1J1	L	Common Return for Signal Ground
*	Join the above wire numbers (Red) to FT-HUD-195A 22 (18" long) free end to 1J1/L.				
**	(6) TPS 22	FT-HUD-127A 22	19J1	N	Sparrow Select Ret
**	22	FT-HUD-196A 22	1J1	e	Power Ground
**	Join the above wire numbers (Red) to FT-HUD-196A 22 (18 inches long), free end to pin 1J1/e with wire number FT-HUD-191A 22.				

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3.3 THE FEEDHORN MODIFICATIONS

The antenna radiation characteristics were modified by changing the RF beam shaping contour of the feedhorn. The effect of this change was a small reduction in the main-beam gain with a significant reduction in the far-sidelobe levels. The suppressor was also modified as part of this change. The parts in the feedhorn affected by this change are shown in figure 3-6.

3.4 DIGITAL AUTOMATIC ACQUISITION MODIFICATION KIT

ECP 7195 directed a redesign of LRU 20. This redesign led to space being available in LRU 20. By further removal and redesign of the 600 Vdc supply the entire LRU was available to be utilized for the digital automatic acquisition circuitry.

The circuitry added to the system consists of a pulsewidth discriminator, digital target detector, boxcar, and lobing modulation detector (LMD), and a +5-volt power supply (see figure 3-7).

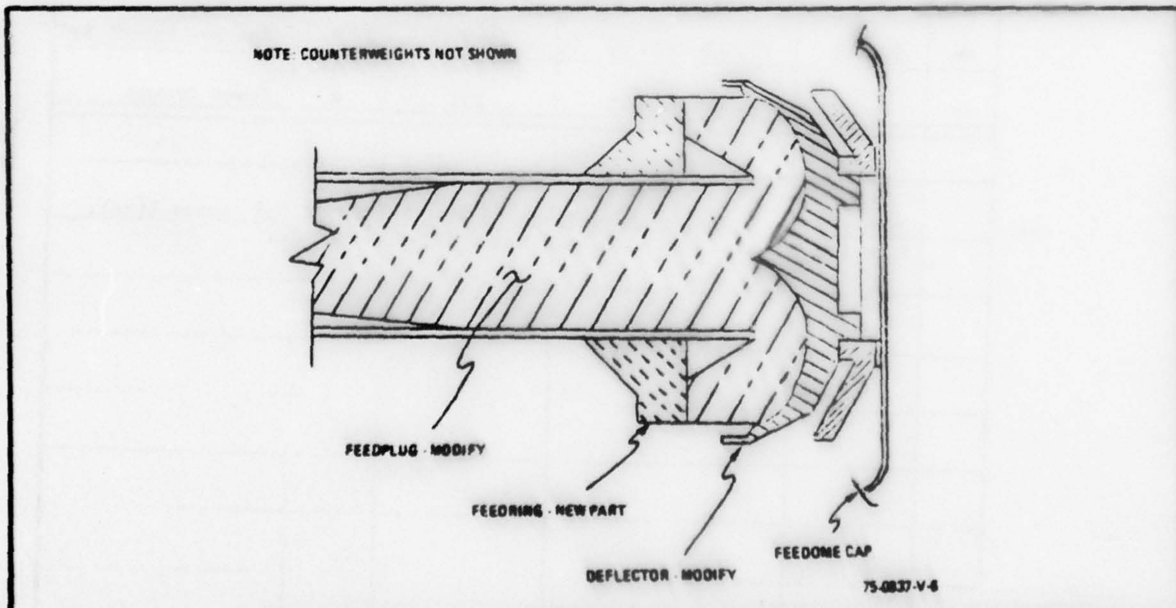

Figure 3-6. Reduced Far Sidelobe Feedhorn

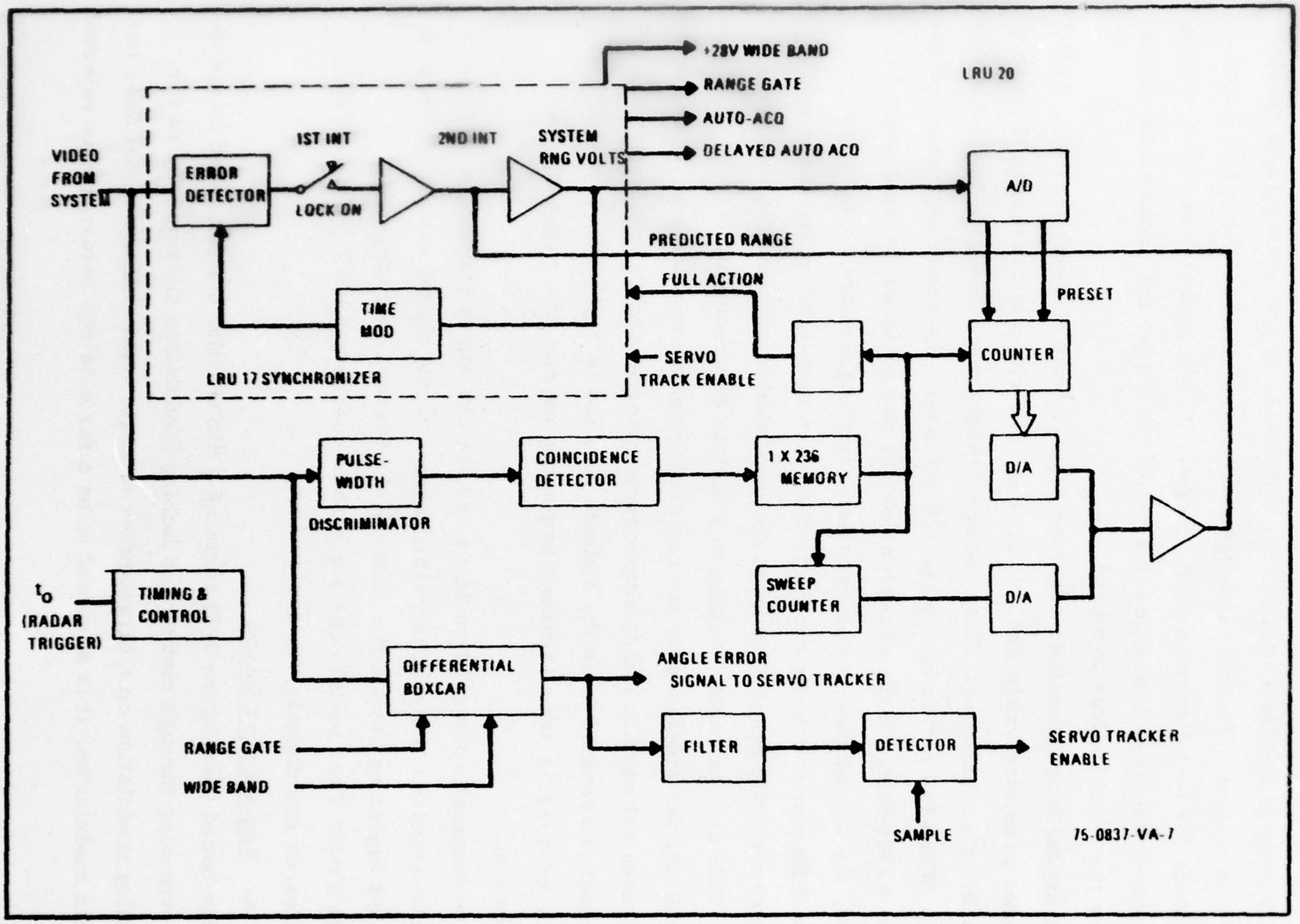

Figure 3-7. Automatic Acquisition

The boxcar is a differential boxcar which aids in preventing angle track transfer to clutter. The digital target detector is used in Automatic Acquisition Mode for fast detection of the target. It then presets the range voltage in the synchronizer to a position in front of the target and applies full action to allow the synchronizer to sweep.

The digital target detector receives signals from the synchronizer, LRU 17, and sends predicted range and full action. The video is processed through the pulsewidth discriminator. This voltage presets the range gate in front of the target. When full action is applied 128 ms later, the predicted range voltage sweeps ±1700 feet. If the synchronizer has not acquired a target after 2-1/2 sweeps, the digital detector is recycled, starting a search cyle again.

The differential boxcar subtracts the video contained in the range cell following the split range gate from the information contained in the range gate. This aids in angle tracking in a clutter environment.

Since the far sidelobes do not contain lobing information and if the acquired signal does not contain lobing components prior to angle track initiation, the signal is assumed to be the altitude line and is rejected. A new digital search process is then initiated beginning beyond the range of the altitude line.

If in Automatic Acquisition Mode and the system is tracking a target and the auto-acquisition button is pushed again, a new digital search process is initiated beginning beyond the range of the lost tracked target.

The Flight Test Model consists of four boards and a 5V power supply. Two boards are digital, two are analog:

a. Angle Error Board

This board (see figure 3-8) contains a differential boxcar, used to aid in angle tracking through clutter and Lobing Modulation Detector, used for detecting modulation on a target prior to angle track. If the signal does not contain modulation, it is assumed to be a far sidelobe return and is rejected.

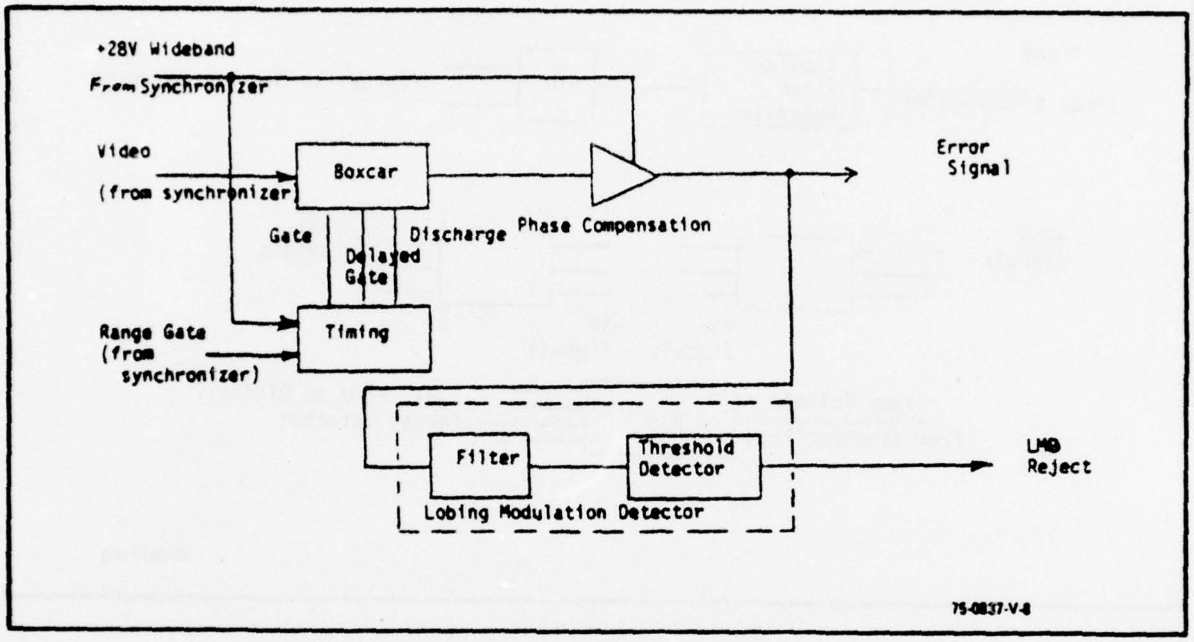

Figure 3-8. Angle Error Board

b. Analog Board

This board (see figure 3-9) contains a bipolar video generator, used for the pulsewidth discriminator and an A/D converter for converting the system range voltage. It also contains several circuits for translating the 5V and 28V signals, and ± 15-volt regulators.

c. Digital Board

These boards comprise the target detection, sweep generator, D/A converter and timing, and then are used to activate the system Full Action line to start the Range Tracking Process.

Also a counter is started, which feeds a D/A voltage. This is summed on the Analog Board with predicted range. This then sweeps the system range voltage over the target.

The system T_o Radar Trigger, starts the oscillator when in Auto-Acquisition Mode. The signal from the bipolar video A/D is then fed into a coincidence detector (see figure 3-10). This is 256 range cell wide. The detector

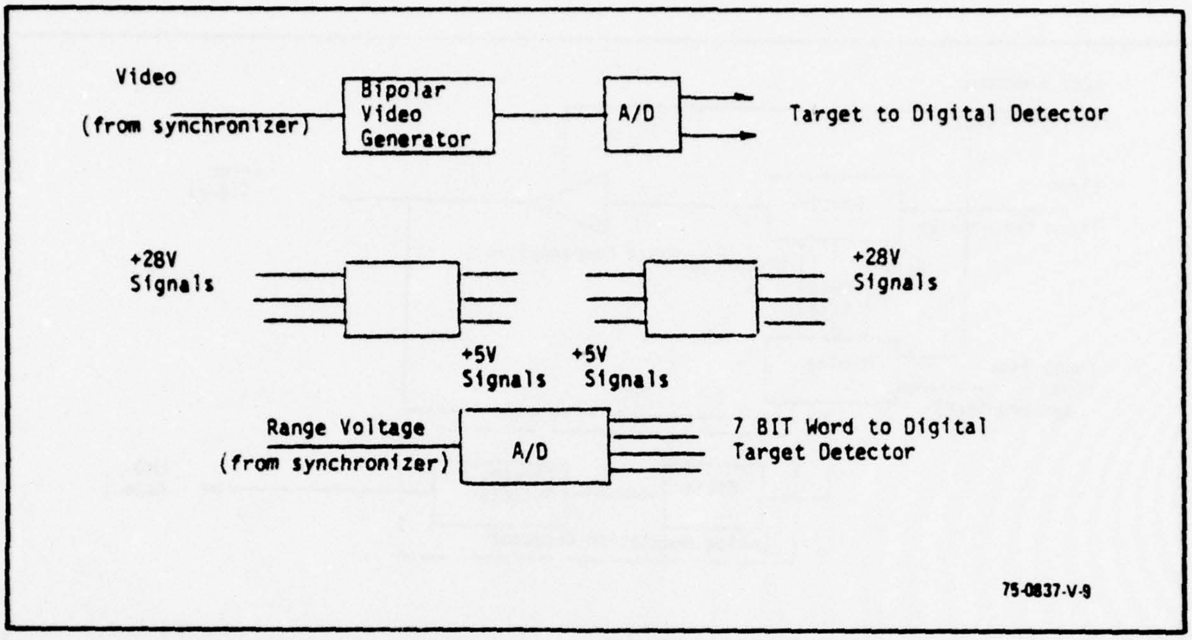

Figure 3-9. Analog Board

consists of an accumulator (integrate and dump) and a threshold detector. The output from the detector is stored in a 1 x 256 memory. A one is stored if the threshold is exceeded, indicating a target is present. After the integration period this memory is addressed looking for the first indication of a target.

The first range cell which is addressed depends on the sequence of events prior to this target detection. If automatic acquisition mode was just entered, the first range cell is equivalent to 900 ft minimum range. If a previous range lock had occurred and the pilot rejected the target, the search begins beyond the target that was being tracked. If an acquisition had occurred and was rejected due to absence of modulation, the search begins three range cells beyond that acquisition.

When the output of the 1 x 256 memory indicates a target is present, the counter which has been addressing it is stopped. This signal is then put through a D/A converter to be sent to the synchronizer to preset the range

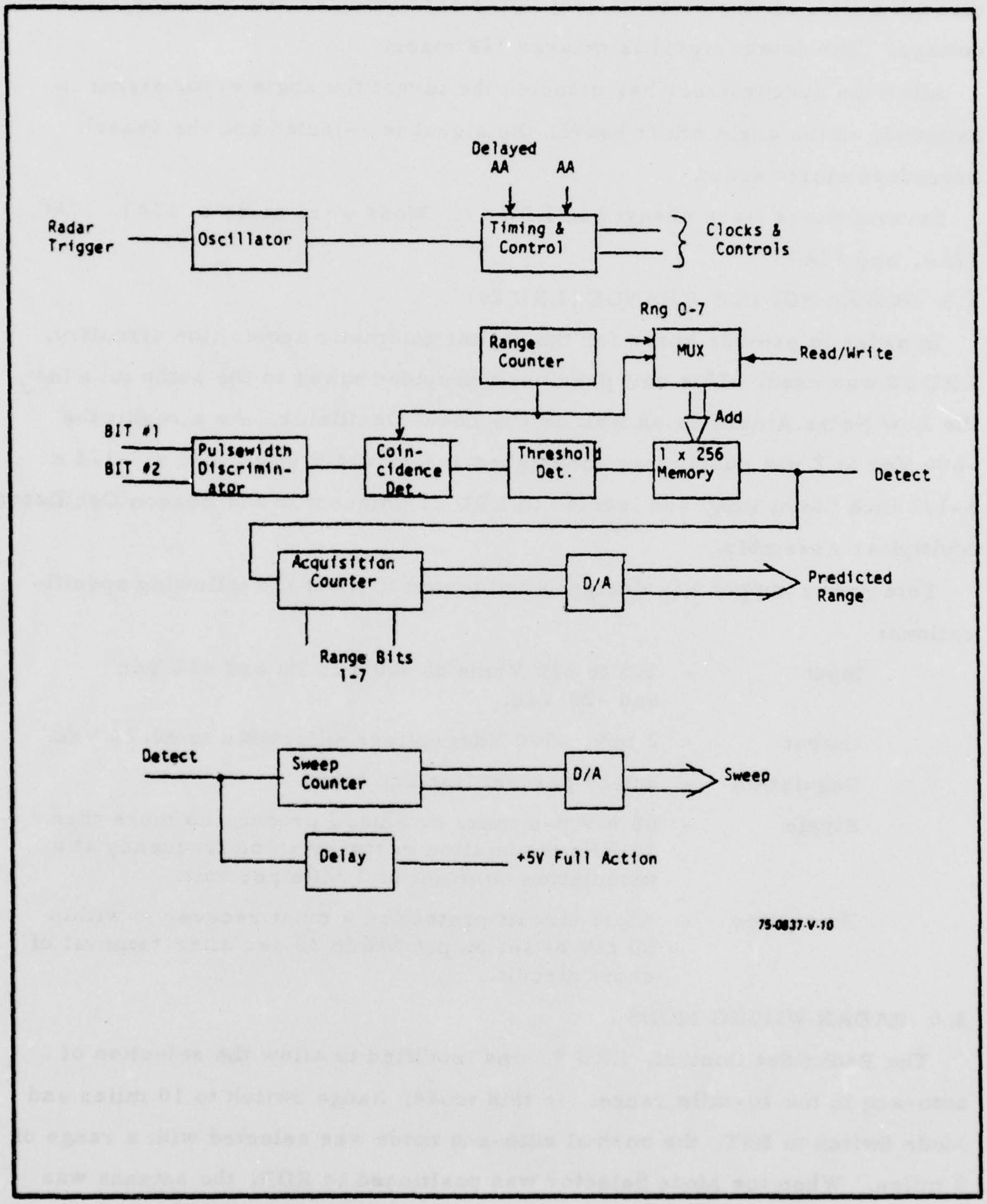

Figure 3-10. Digital Board

through a D/A converter to be sent to the synchronizer to preset the range voltage. The detect signal is delayed 128 msec.

After the synchronizer has detected the target the angle error signal is sampled; on the angle error board, the signal is rejected and the search procedure starts again.

Several wires were changed in LRU 17. Mods were made to 17A3, 17A6, 17A4, and 17A7.

3.5 POWER SUPPLY CHANGE (LRU 21)

In order to provide space for the digital automatic acquisition circuitry, LRU 20 was used. This unit previously provided power to the pump tube in the Low Noise Amplifier as well as the Local Oscillator. As a result the -600 Vdc at 2 mA supply was redesigned and mounted in a 2-1/2 x 2-1/2 x 5-1/2 inch "Mini Box" and located in LRU 21 adjacent to the Beacon Oscillator-Multiplier Assembly.

This power supply was designed and tested to meet the following specifications:

Input	-	108 to 120 Vrms at 400 ±20 Hz and +12 Vdc and -25 Vdc.
Output	-	2 mA, -600 Vdc: voltage adjustable to ±0.25 Vdc.
Regulation	-	±0.25 percent line and load.
Ripple	-	50 mV p-p max, or should produce no more than 10-kHz modulation of the klystron frequency at a modulation constant of 2 MHz per volt.
Protection	-	Short circuit protection - must recover to within 60 mV of set output within 30 sec after removal of short circuit.

3.6 RADAR WIRING MODS

The Radar Set Control, LRU 9, was modified to allow the selection of auto-acq in the 10-mile range. In this mode, Range Switch to 10 miles and Mode Switch to BST, the normal auto-acq mode was selected with a range of 9 miles. When the Mode Selector was positioned to RDR, the antenna was controlled by the AN/AYK-8 computer. A further explanation of this mode is contained in paragraph 3.7.

Connector 20 P-I was disassembled from its present location and inserted into the equipment rack and connected to the new -600 Vdc supply to provide 400 Hz power. The -600 Vdc supply is connected to 19P5 ro provide power to the L. O.

The new Digital Automatic Acquisition LRU which replaces LRU 20 was connected to the synchronizer LRU 17 via a cable to each of the LRU's rather than a cable assembly in order to facilitate this modification. In a normal system configuration which would incorporate digital auto-acq the interconnections between these LRU's would be made via the equipment rack.

3.7 OPERATOR MODE CONTROL CHANGES

The following operator mode control changes were implemented to facilitate flight testing of the radar modifications.

a. Modified Feedhorn

No operator mode control changes were required for testing of the modified feedhorn.

b. Automatic Acquisition

(1) Automatic Acquisition mode is selectable in the normal way, by selecting 5 Mile Range and BST and depressing the Automatic Acquisition Switch. In addition, circuit changes were made so that this mode may be selected by selecting 10 Mile Range, BST and depression of the Automatic Acquisition Button. The maximum range scale examined by the Digital Auto-Acq range circuits was set to approximately 9 miles.

(2) An optional secondary Automatic Acquisition mode was implemented. This was an off-boresight mode. In this mode the antenna is slaved to one of three selectable scan patterns until target detection is initiated. This optional mode was made possible because of the flexability available in the AN/AYK-8 digital computer, which could be mechanized through a software modification to generate the required scan patterns for directing the antenna.

This mode was selected by the 10 Mile Range Switch and the depression of the Automatic Acquisition Button. The scan pattern and certain scan pattern functions were selectable from the rear seat Computer Control Panel. The computer is excited by placing the mode control switch in OPR or OPR/ ACE.

3.7.1 Auto Acq Scan Pattern Select

The scan pattern is selected as follows:

a. Rotate the upper Display Index thumbwheel to the number 6.

b. Depress the KBD button. This sets up the keyboard functions.

c. Depress the desired scan pattern number on the 10 digit keyboard.

The selected number will appear in the upper right numeral display.

d. Depress KBD, this has the effect of entering the selected scan pattern number in the operational program and turning off the keyboard function.

The scan pattern number code is given below:

0 (or any single digit number other than 1 of 2),

Elevation Scan

Scan Rate: 60 deg/sec
1 Bar
Azimuth: 0 deg (through R. B. L.)
Elevation Coverage: -10 to +50 deg

1, Box Scan

Scan Rate: 60 deg/sec
6 Bars: 3 deg between bars
Azimuth Coverage: ± 15 deg
Elevation Coverage: -11 to +4 deg

2, Azimuth Scan

Scan Rate: 60 deg/sec
1 Bar
Azimuth Coverage: ±24 deg
Elevation: 0 deg (through R. B. L.)

3.7.2 Antenna Backup

When a target is detected the synchronizer supplies a Stop Scan signal to the computer. Since the antenna will move past the target a small amount before the Stop Scan signal becomes effective, due to time delays, scan

pattern update rate, etc, a backup increment is added to the antenna stop position to account for this effect. The amount of the backup increment is selectable, on the Computer Control Panel, in the same manner as the Auto Acq Scan Pattern number. In this case, however, the upper thumbwheel is rotated to the number 7 and the desired backup increment, in tenths of a degree, is entered into the 10 digit keyboard.

3.7.3 Antenna Jump Ahead

If the radar should lock-up on clutter and lock-up is therefore rejected, the scan pattern would be resumed at the current antenna position. There is a high probability that the radar would then reacquire clutter. A small increment or jump is therefore added to the antenna position from which the scan is to be resumed so that clutter will be bypassed. The jump angle is selectable from the Computer Control Panel in the same way that the Scan Pattern number and the Antenna Backup angle are selected. In this case, however, the number 8 is selected on the upper thumbwheel and the jump angle, in tenths of a degree is entered into the 10 digit keyboard.

3.7.4 Beacon Track

No change in Operator Mode Control was made for this function. The radar has been modified for beacons to be accepted as normal targets for tracking purposes. This mode was not tested during the flight test since a suitable beacon for test was not available.

3.8 COMPUTER CONTROL PANEL

The Computer Control Panel (CCP) is located in the rear cockpit on the right side (see figure 3-11).

a. Submode Switch

This is the main computer control switch, with five positions: TEST PATTERN, OFF, OPERATE, OPERATE/ACE and MODE TEST.

TEST PATTERN - This submode is a computer standby mode. The test pattern is presented on the HUD. The RAYMOND TAPE HANDLER will not record in this mode.

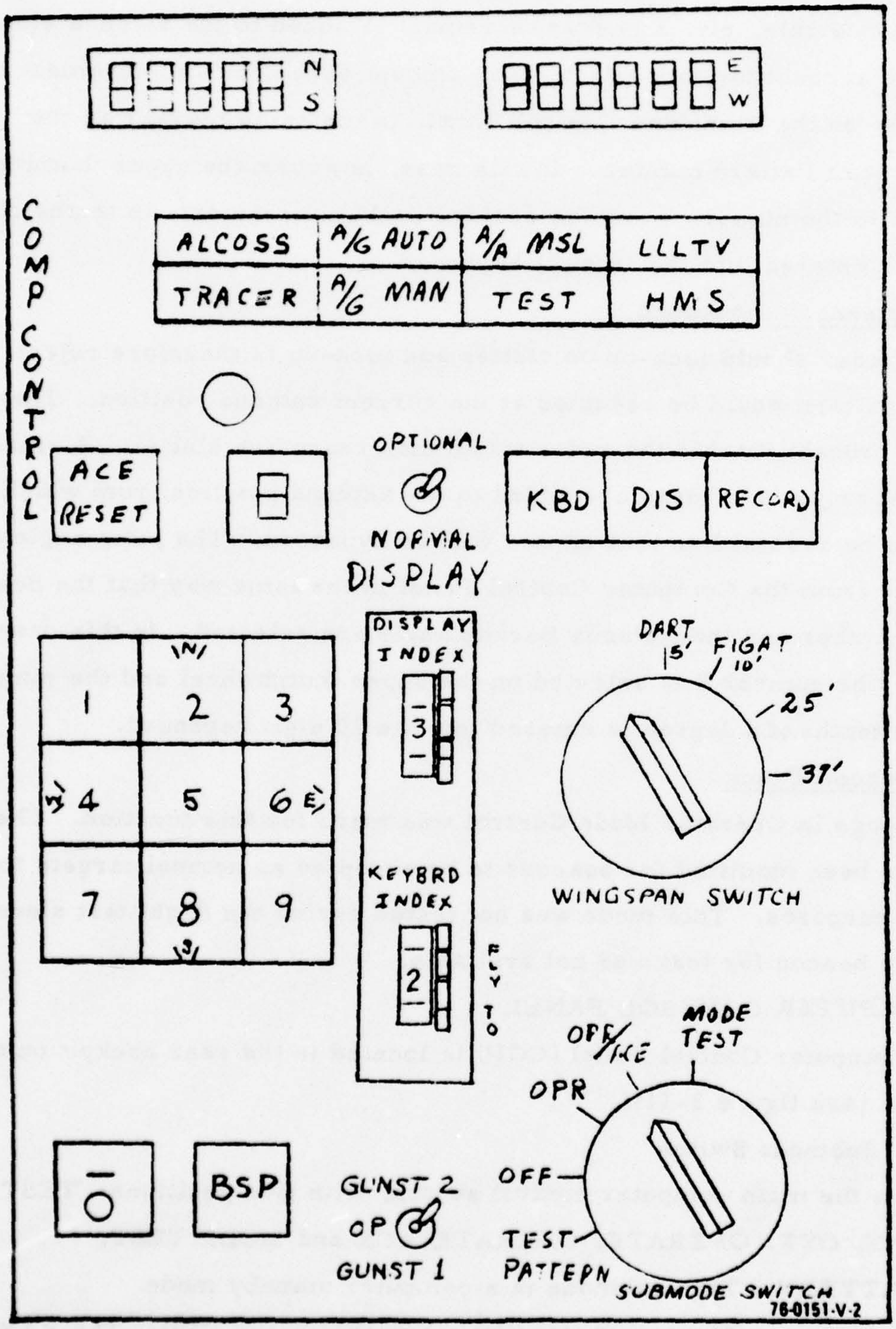

Figure 3-11. Computer Control Panel

OFF	-	Turns off all power to computer. The HUD will be blank even though it is on. Turning back on reinitializes computer program.
OPERATE	-	This is normal on position. The program algorithms use the aircraft data to control symbols on HUD. The mode switch on HUD in front cockpit controls mode.
OPERATE/ACE	-	Same as operate with ACE. ACE currently not operational.
MODE TEST	-	Uses computer program to generate dynamic data for display package. This moves symbols in random motion on HUD.

b. GUNTEST Switch

This is a three-position toggle switch used by the TRACER and ALCOSS algorithms.

OPERATE	-	This is the normal position. The algorithms use aircraft data.
GUN TEST 1	-	Static data is used in algorithms to generate a static HUD display.
GUN TEST 2	-	This is the same as GUN TEST 1 except range is slowly changed.

c. TIMING ERROR Light

This light is software controlled - it is illuminated when the Computer Cycle time exceeds 62.5 msecs. (This is currently not operational; however if the light comes on recycling the computer is necessary to reset serial data.)

d. WINGSPAN Switch

The main function of this 12 position switch is for wingspan selection. The wingspan is used by the gunnery routines in conjunction with the stadiametric ranging wheel on the throttle to estimate target range. Four wingspans can be selected: 5 feet, 10 feet, 25 feet, and 37 feet at 12, 1, 2 and 3 o'clock respectively. Any other switch position will give a wingspan of zero.

The Raymond tape handler is rewound by putting this switch in the 9 o'clock position and recycling the computer by turning on.

e. Keyboard Button - KBD

This pushbutton is used to enable the KEYBOARD. Pushing it once will light the button and the KEYBOARD will also be lit. Numbers can now be entered to the right numerical display at the top of the panel. If a mistake is made when entering a number the backspace button (BSP) can be used to delete the last digit. The button is pressed again to enter the number displayed.

f. KEYBOARD

This 11 pushbutton array is used to enter numbers. The largest decimal integer that can be entered is 131071. The backspace button is used to delete the last digit. The keyboard lights up dimly when it is enabled by the KBD button.

g. DISPLAY Button - DIS

When this button is pressed, it lights up and a number is displayed in the right numerical display at the top of the panel. The item which is displayed is controlled by the top thumbwheel position. Turn off by pushing again.

h. Thumbwheel - Top

This eight position thumbwheel switch is used to choose an item to be displayed or to be modified by using the keyboard. The following items are currently available:

(1) Air-Ground Manual Solution Number. Enter or display a decimal number 0-11 to choose presets from solution table. A number greater than 11 will cause default to 0.

(2) Target Height - Enter or display the number of feet that the target is above sea level. This number is used in the A-G manual and Auto solutions.

(3) Rounds - Initialize the number of rounds loaded into the gun by entering through keyboard. The number of rounds remaining can be continuously displayed.

(4) Contents of any Core Location - Any core location $0\text{-}37777_8$ is entered in octal through keyboard. The contents of this location are displayed in octal in the right numerical display.

(5) Flight Number - Enter or display any decimal number (0-64535 because 16-bit) to be recorded at the beginning of each RAYMOND TAPE Record.

(6) Radar Scan Pattern Number - Enter or display scan pattern number for digital auto acq. Entering a number greater than 2 will default to 0.

0, Default, elevation fan scan

Rate: 60 deg/sec
1 Bar: Thru R. B. L.
Azimuth: Thru Radar Boresight Line
Elevation: -10 to +50 deg

1, Box Scan

Rate: 60 deg/sec
6 Bars: 3 deg between bars
Azimuth: -15 to +15 deg
Elevation: -11 to +4 deg, 3 deg between bars

2, Azimuth Scan

Rate: 60 deg/sec
1 Bar: Thru R. B. L.
Azimuth: -24 to +24 deg
Elevation: Thru R. B. L.

(7) Antenna Back-up - Enter or display amount of antenna backup in tenths of degrees. No default, the last value entered is used.

(8) Antenna Jump Ahead - Enter of display amount of antenna jump in tenths of degrees. Jump ahead after rejection to increment out of ground clutter. No default, the last value entered is used.

i. RECORD Button - REC

Pressing once turns on, pressing again turns off. Controls continuous recording of RAYMOND TAPE HANDLER. The SUBMODE switch must be in operate and the MODE switch on the HUD cannot be in the standby, then pushing this button ON records 16 frames of data per second on tape. This is used in addition to DETENT 1 which causes noncontinuous recording.

j. Annunciator Lights

Eight light panels below numerical displays at top of panel. This indicates to the rear cockpit the mode which has been chosen by the pilot using the MODE switch on the HUD. The 8 modes that can be displayed are: ALCOSS, TRACER, A/G AUTO, A/G MANUAL, MISSLE, TEST, LLLTV, HMS. The last three are not currently operational.

k. Recorder Status Number - This single digit numerical display indicates the status of the RAYMOND TAPE HANDLER.

0 moving either forward or reverse
1 Malfunction
2 Malfunction
3 Malfunction
4 Stopped
5 Stopped, beginning of tape.
6 Stopped, end of tape.
7 Malfunction or unit not connected.

l. ACE Reset

This button is to be used to reset software for ACE which is not currently operational. It is currently used to set and reset 8 options chosen by the lower thumbwheel switch. The status of the option dialed is displayed in the left numerical display at the top of the panel.

m. LOWER THUMBWHEEL SWITCH

This 8 position switch is used to set or clear eight option flags. If the number 2 is dialed in and OPTION 2 is off, 20000 is displayed in the left numerical display at the top of the panel. Pressing the ACE RESET button will set OPTION 2 and 22220 will be displayed. The following options are currently used:

(1) Move symbols closer to center of TFOV

(2) A/G Manual-Dive angle indicator relative to center of scales instead of velocity vector.

(3) Bypass some INS inputs in A/G Auto. Do not use Heading or East, North, Vertical Velocities. Essentially give wind-free solution.

(4) Display g's and time instead of rounds remaining in TRACER and ALCOSS modes.

(5) Change A/G Auto mode to A/G Manual. Used in case of Weopon select switch malfunction in DIRECT position.

(6) Spare

(7) Spare

(8) Spare

m. OPTIONAL/NORMAL Switch

This switch changes HUD display between OPTIONAL SET and NORMAL SET. The OPTIONAL SET are the normal symbols for that mode plus one or more optional symbols.

o. PANEL FAULT Light

This is a hardware controlled light which, when lit, indicates a malfunction with the computer control panel.

3.9 SOFTWARE CHANGES

The operational program of the AYK-8 computer was modified to include a subprogram for generating a scan pattern to drive the antenna when the secondary Slaved Automatic Acquisition mode is selected. A selection of three scan patterns were provided. In addition, provisions were made to adjust the backup angle increment at stop scan and the jump angle increment at resume scan. The scan patterns, backup angle, jump angle, and selection procedure are described more fully in paragraph 3.7. Flow diagrams of the scan pattern program are given in figures 3-12 and 3-13. The scan pattern update rate was 150 Hz.

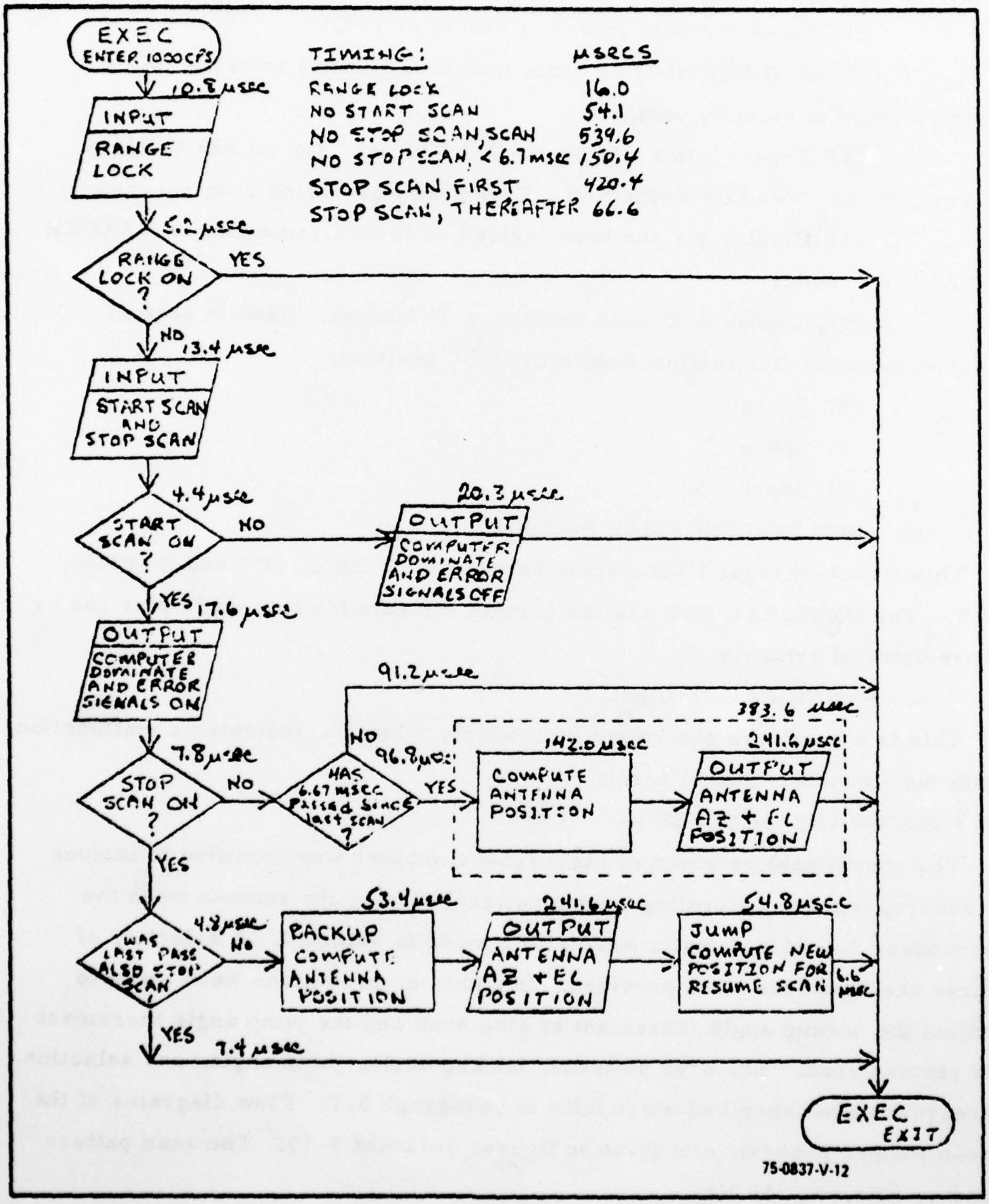

Figure 3-12. Digital Auto-Acquisition

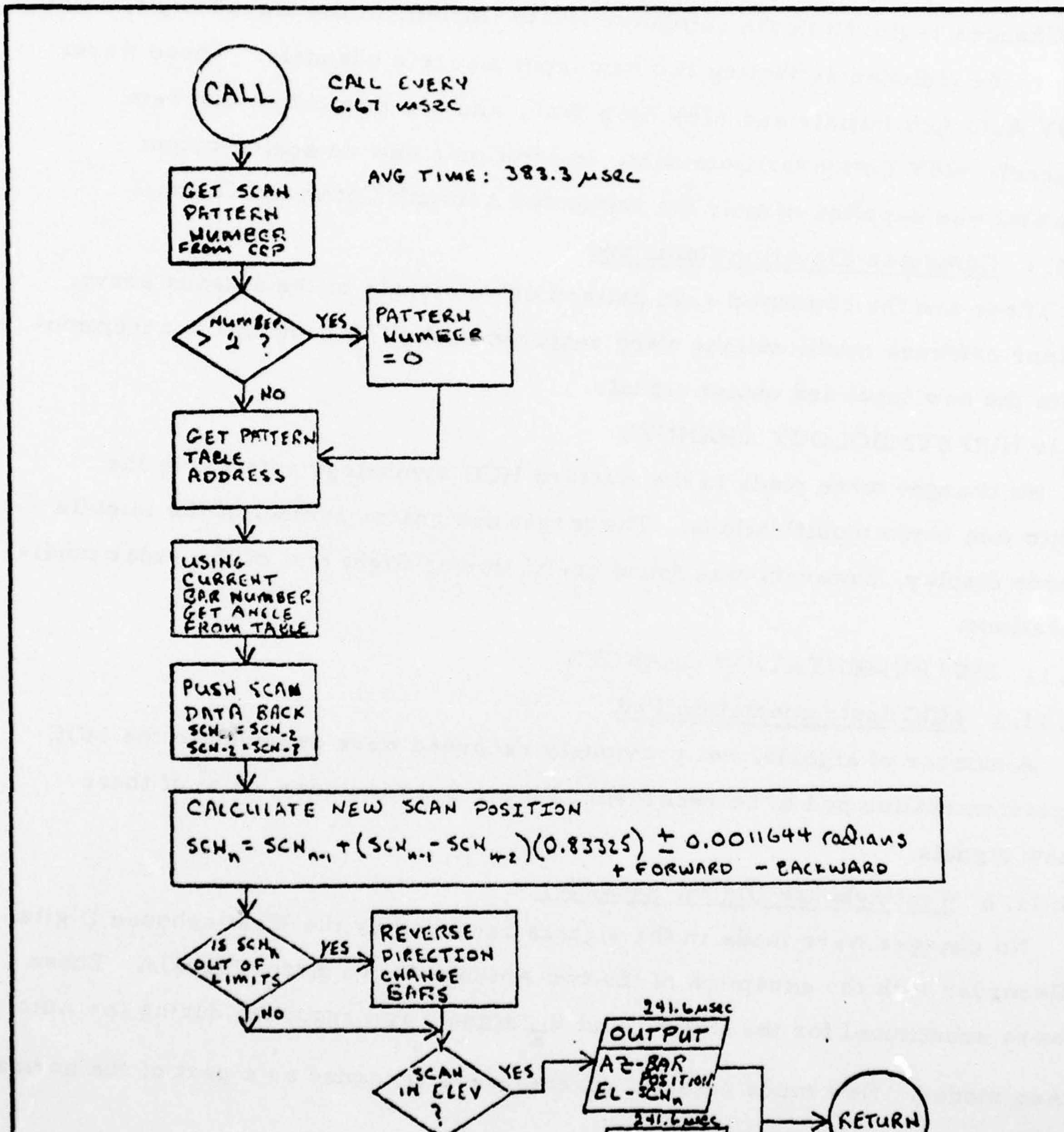

Figure 3-13. Antenna Scan

Changes required in the computer I/O to implement the Slaved Digital Auto Acq mode included activating two new input discrete channels. These were: +28V Auto Acq Initiate and +28V Stop Scan, and one new output discrete channel, +28V Computer Dominant. In addition a new dc analog output channel was supplied namely the Computer Azimuth Command Channel

3.9.1 Computer Elevation Command

These are the computed scan pattern drive signals to the antenna servo. Minor software modifications were required in the I/O program to accommodate the new input and output signals.

3.10 HUD SYMBOLOGY CHANGES

No changes were made in the Austere HUD symbology relative to the Auto Acq mode modifications. The target designator symbol of the missile mode display, however, was found useful during flight test of the radar modifications.

3.11 INSTRUMENTATION CHANGES

3.11.1 MDC Instrumentation Pod

A number of signals, not previously recorded were provided to the MDC Instrumentation pod to be recorded. Figure 3-14 includes a list of these new signals.

3.11.2 Westinghouse Digital Recorder

No changes were made in the signals recorded by the Westinghouse Digital Recorder with the exception of the two Antenna Servo Error Signals. These were substituted for the INS V_N and V_E signals and recorded during the Auto Acq modes. New mode select discretes were recorded as a part of the normal discrete recording program.

3.11.3 Westinghouse Video Recorder

To determine the characteristics of the video return from the altitude line, a Sony AV3400 Videocorder was purchased for installation in the instrumentation pod of A/C 304. The radar video and T_o trigger were summed and attenuated to prodice a composite self-triggering signal. This proved to be

an invaluable aid for determining the circuit approach which would best discriminate against the altitude line.

SIGNAL	RANGE	HORN REQD	A*	DIGITAL AUTO. ACQ. REQUIRED	A*
1. RANGE VOLTAGE	0 TO +200 VDC	X		X	
2. RANGE RATE	-30 TO +6 VDC	X		X	
3. INS ROLL		X			
4. INS PITCH		X			
5. 28V HALF ACTION		X			
6. 22V FULL ACTION		X			
7. 28V SKIN TRACK		X		X	
8. PREAMP AGC	-20 TO +50 VDC	X		X	
9. FERRITE AGC	+10V TO +50 VDC	X		X	
10. ANTENNA POSITION EL	+ OR - 15 VDC	X		X	
11. ANTENNA POSITION AZ	+ OR - 15 VDC	X		X	
12. +250VDC REFERENCE		X			
13. 28V 2ND ORDER TRACK			X		
14. 23V COM #2			X		
15. 28V MANUAL TRACK			X		
16. ALTITUDE		X		X	

*A = DESIRABLE, BUT NOT ABSOLUTELY NECESSARY

FEED HORN AND AUTOMATIC ACQUISITION REPORTS IN MAIL.

J 3 GREGORY MS 450 AESD WESTINGHOUSE D&ESC BALTIMORE MD EJ

PROCEDUAFB

75-0837-V-14

Figure 3-14. Analog Instrumentation Changes

3.12 GROUND SUPPORT SOFTWARE CHANGES

No ground support software package changes were made as a part of the feedhorn/auto acquisition phase of the test program. Thus the same programs at SEAFAC, AFA Westinghouse Baltimore, Honeywell Minneapolis, and AFFTC were available and were used as needed.

A change in the program to transcribe the airborne digital tape recorder to the ground computer compatible with magnetic tape was made and tested.

A summary of the utility routines for this phase of the program is contained in Appendix A11.

3.13 INTEGRATION PHASE

The radar modifications made and tested were intended to improve radar target acquisition and tracking performance by suppressing the effects of altitude line clutter. Two basic modifications were made:

a. Sidelobe suppression was accomplished through an improved feedhorn design, consequently reducing altitude line clutter.

b. An improved target acquisition technique was employed with inherent altitude line rejection characteristics which were superior to those previously implemented in modern radars.

Since it was anticipated that all APQ-120 radars would be modified to the ECN 13 IFF configuration, it was specified that this configuration should be used during flight test. Consequently a GFE production configuration antenna was shipped to Westinghouse for the installation of ECN 13. Routine testing of the antenna indicated that refurbishment was necessary before any modifications could be made. This was accomplished by the cooperation of all persons involved in the flight test effort. Three sets of antenna gain patterns were made:

a. Original antenna configuration

b. ECN 13 configuration with standard feedhorn and suppressor plate

c. ECN 13 configuration with modified feedhorn and suppressor plate.

The antenna with ECN 13 and the standard feedhorn incorporated was then shipped to Edwards AFB, Calif. for installation in the aircraft. A modified radome compatible with ECN 13 was located at Edwards AFB and also installed.

A digital automatic acquisition technique designed for improved altitude line rejection characteristics was employed in the target acquisition circuit modifications.

The auto acquisition hardware mechanization was incorporated and verified on a bench system at Baltimore before shipment to Edwards AFB. The digital scan program was verified on the computer bench at Edwards AFB. Integration of the modified computer hardware, software, auto acquisition circuitry, and the APQ-120 was conducted on the aircraft at Edwards. After ground checkout of the system, further adjustments and modification were made based upon data recorded in flight.

3.14 FLIGHT TEST PLAN

Appendix A contains the AFFTC Test Plan for Phase D avionics update (AN/APQ-120 altitude line/auto-acq) dated April 1975. The original schedules included flights during the months of May, June, July, and August. A/C 304 was scheduled to be flown to Hill AFB for mechanical modifications Sept. 3, 1975 after completion of the Phase D flight test. The schedule was met approximately 2 weeks prior to anticipated conclusion.

3.15 FLIGHT TEST OBJECTIVES

In the following pages are included the objectives of the 49 flights and whether or not data was collected. Adding all of the actual specifics of the data would only lengthen this report. These specifics, however, were used in paragraph 3.15 (Analysis of Flight Test Results).

1. Mission Number: 332 Aircraft Serial No. 68-0304 1.5 hours
   Date: 13 May 1975
   Crew: Maj. D. W. Milam/LCol. K. W. Brotnov
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - max range over land
   Result: 5 data points

2. Mission Number: 333 Aircraft Serial No. 68-0304 1.6 hours
   Date: 14 May 1975
   Crew: Capt. J. H. Casper/LCol. K. W. Brotnov
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - max range over land
   Result: 8 data points

3. Mission Number: 334 Aircraft Serial No. 68-0304 1.5 hours
   Date: 15 May 1975
   Crew: Capt. J. H. Casper/LCol. K. W. Brotnov
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - altitude line over water
   Result: 18 data points

4. Mission Number: 335 Aircraft Serial No. 68-0304 1.7 hours
   Date: 21 May 1975
   Crew: Capt. J. H. Casper/Capt. B. G. Stohl
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - altitude line over water
   Result: 21 data points

5. Mission Number: 336 Aircraft Serial No. 68-0304 1.8 hours
   Date: 22 May 1975
   Crew: Capt. J. H. Casper/LCol. K. W. Brotnov
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - max range over land
   Result: 9 data points

6. Mission Number: 337 Aircraft Serial No. 68-0304 1.5 hours
   Date: 23 May 1975
   Crew: Capt. J. H. Casper/Capt. B. G. Stohl
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - altitude line over land
   Result: 23 data points

7. Mission Number: 338 Aircraft Serial No. 68-0304 1.3 hours
   Date: 27 May 1975
   Crew: Capt. J. H. Casper/Capt. B. G. Stohl
   Radar Configuration: Conventional feedhorn/auto-acq
   Objective: Baseline data - altitude line over land
   Result: 20 data points

8. Mission Number: 339 Aircraft Serial No. 68-0304 FCF
Date: 18 June 1975
Crew: Capt. E. T. Meschko/LCol. K. W. Brotnov
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Functional check flight (FCF) after engine change
Result: No data

9. Mission Number: 340 Aircraft Serial No. 68-0304 1.8 hours
Date: 19 June 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - max range over land - clutter runs
Result: No data (antenna boresight 3° down)

10. Mission Number: 341 Aircraft Serial No. 68-0304 1.7 hours
Date: 21 June 1975
Crew: Capt. E. T. Meschko/Capt. B.G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - max range over land
Result: No data (antenna boresight 3° down)

11. Mission Number: 342 Aircraft Serial No. 68-0304 1.5 hours
Date: 26 June 1975
Crew: Capt. E. T. Meschko/LCol. K. W. Brotnov
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - max range
Result: 7 data points

12. Mission Number: 343 Aircraft Serial No. 68-0304 1.7 hours
Date: 27 June 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - auto-acq
Result: No data - STC level would not allow lock-on

13. Mission Number: 344 Aircraft Serial No. 68-0304 1.7 hours
Date: 27 June 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - auto-acq - clutter over water
Result: No data - STC level experimentation

14. Mission Number: 345 Aircraft Serial No. 68-0304 1.5 hours
Date: 28 June 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collection - altitude line over water
Result: 20 data points (AGC instrumentation inoperative)

15. Mission Number: 346 Aircraft Serial No. 66-0368 1.4 hours
*Same radar system as 68-0304
Date: 1 July 1975
Crew: Maj. J. F. Aitken/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collection - altitude line over water
Result: 20 data points

16. Mission Number: 347 Aircraft Serial No. 66-0368 1.5 hours
Date: 1 July 1975
Crew: Capt. J. H. Casper/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collect - altitude line - clutter runs over land
Result: 20 data points - No clutter data (AGC instr. malfunction)

17. Mission Number: 348 Aircraft Serial No. 66-0368 1.4 hours
Date: 3 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collection - max range
Result: 12 data points (AGC instrumentation malfunction)

18. Mission Number: 349 Aircraft Serial No. 66-0368 1.6 hours
Date: 3 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collect - auto-acq - clutter runs over water
Result: 100 data points over water - No data (AGC instr.
14 data points over land malfunction) for clutter

19. Mission Number: 350 Aircraft Serial No. 66-0368 1.6 hours
Date: 7 July 1975
Crew: Capt. J. H. Casper/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collection - auto-acq - altitude line
Result: 60 data points - 22 data points

20. Mission Number: 351 Aircraft Serial No. 66-0368 1.7 hours
Date: 7 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collect - max range - auto-acq - clutter over land
Result: 8 data points - 40 data points - 2 data points

*Except Westinghouse DVST indicators vs TI scan converter.

21. Mission Number: 352 Aircraft Serial No. 66-0368 1.7 hours
Date: 8 July 1975
Crew: Capt. J. H. Casper/Capt. B. G. Stohl
Radar Configuration: New feedhorn, conventional auto-acq
Objective: Data collect - max range - clutter runs over water
Result: 6 data points - 2 data points (1 data point over land)

22. Mission Number: 353 Aircraft Serial No. 66-0368 1.7 hours
Date: 9 July 1975
Crew: Capt. J. H. Casper/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - auto-acq - clutter runs over water
Result: 100 data points - 2-3 data points

23. Mission Number: 354 Aircraft Serial No. 66-0368 1.6 hours
Date: 9 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - auto-acq - max range over land
Result: 100 data points - 6 data points

24. Mission Number: 355 Aircraft Serial No. 66-0368 1.6 hours
Date: 10 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn/auto-acq
Objective: Baseline data - max range over land
Result: 21 data points

25. Mission Number: 356 Aircraft Serial No. 68-0304 1.6 hours
Date: 23 July 1975
Crew: Capt. J. H. Casper/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Data collect - auto-acq - altitude line over land
Result: No auto-acq data - 41 data points

26. Mission Number: 357 Aircraft Serial No. 68-0304 1.8 hours
Date: 23 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Data collect - max range - auto-acq - clutter runs over water
Result: 10 data points - No data - 2 data points (repeats)

27. Mission Number: 358 Aircraft Serial No. 68-0304 1.8 hours
Date: 24 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Max range - auto-acq - clutter over land
Result: 14 data point - no data - repeats

28. Mission Number: 359 Aircraft Serial No. 68-0304 1.6 hours
Date: 24 July 1975
Crew: Maj. J. F. Aitken/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Altitude line - auto-acq - clutter over water
Result: 20 data points - no data - no data

29. Mission Number: 360 Aircraft Serial No. 68-0304 1.6 hours
Date: 25 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Altitude line - auto-acq - clutter over water
Result: 16 data points - 80 data points - no data

30. Mission Number: 361 Aircraft Serial No. 68-0304 1.6 hours
Date: 25 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Altitude line - auto-acq - clutter over water
Result: 6 data points - 247 data points - no data

31. Mission Number: 362 Aircraft Serial No. 68-0304 1.3 hours
Date: 25 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Data collection - auto-acq over land
Result: 280 data points

32. Mission Number: 363 Aircraft Serial No. 68-0304 1.5 hours
Date: 28 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn, digital auto-acq
Objective: Data collection - altitude line - auto-acq over land
Result: 25 data points - 164 data points

33. Mission Number: 364 Aircraft Serial No. 68-0304 1.5 hours
Date: 29 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn, digital auto-acq
Objective: Data collection - altitude line - auto-acq over water
Result: 24 data points - 125 data points

34. Mission Number: 365 Aircraft Serial No. 68-0304 1.8 hours
Date: 29 July 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: Conventional feedhorn, digital auto-acq
Objective: Data collection - altitude line - auto-acq
Result: 10 data points over land - 82 data points over land
17 data points over water - 99 data points over water

AD-A042 255 WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 19/5
F-4E FIRE CONTROL SYSTEM SIMULATOR, F-4E AUSTERE/HEADS UP DISPL--ETC(U)
MAY 77 W PATTERSON F33615-74-C-1173

UNCLASSIFIED AFAL-TR-76-190 NL

5 OF 5
AD
A042255

END

DATE
FILMED
8-77

35\. Mission Number: 366 Aircraft Serial No. 68-0304 1.7 hours
Date: 31 July 1975
Crew: Record was not available
Radar Configuration: New feedhorn, digital auto-acq
Objective: Elevation scan characteristics
Result: Evaluated beam/scan widths and antenna backup increment

36\. Mission Number: 367 Aircraft Serial No. 68-0304 1.6 hours
Date: 1 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Check out elevation scan
Result: Evaluated beam/scan width characteristics and antenna backup increment after software changes

37\. Mission Number: 368 Aircraft Serial No. 68-0304 1.5 hours
Date: 1 August 1975
Crew: Maj. J. F. Aitken/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Check out box-scan characteristics
Result: Evaluated box-scan characteristics - Experiment with backup increment options

38\. Mission Number: 369 Aircraft Serial No. 68-0304 1.8 hours
Date: 4 August 1975
Crew: Record was not available
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate elevation and azimuth scans and
Result: antenna backup increment options

39\. Mission Number: 370 Aircraft Serial No. 68-0304 1.6 hours
Date: 5 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate box-scan and azimuth scan characteristics
Result: (pilot prefers elevation scan)

40\. Mission Number: 371 Aircraft Serial No. 68-0304 1.1 hours
Date: 6 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate restart of various scans after software
Result: change

41. Mission Number: 372 Aircraft Serial No. 68-0304 0.7 hour
Date: 11 August 1975
Crew: Maj. J. Moran/Capt. W. Smith
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate digital auto-acq (boresight) in Air Combat Maneuver environment- Aggressor Squadron crew checkout/familiarization
Result:

42. Mission Number: 373 Aircraft Serial No. 68-0304 0.6 hour
Date: 11 August 1975
Crew: Maj. J. Moran/Capt. W. Smith
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate elevation scan digital auto-acq in Air Combat Maneuver environment
Result:

43. Mission Number: 374 Aircraft Serial No. 68-0304 0.7 hour
Date: 12 August 1975
Crew: Maj. J. Moran/Capt. W. Smith
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate elevation scan digital auto-acq in Air Combat Maneuver environment
Result:

44. Mission Number: 375 Aircraft Serial No. 68-0304 0.8 hour
Date: 12 August 1975
Crew: Maj. J. Moran/Capt. W. Smith
Radar Configuration: New feedhorn, digital auto-acq
Objective: Evaluate azimuth and box scan characteristics of digital auto-acq in Air Combat Maneuver environment (Pilot experienced great difficulty in locking up)
Result:

45. Mission Number: 376 Aircraft Serial No. 68-0304 0.8 hour
Date: 13 August 1975
Crew: Maj. J. Moran/Capt. W. Smith
Radar Configuration: New feedhorn
Objective: Evaluate azimuth and box scan characteristics of digital auto-acq in Air Combat Maneuver environment (Pilot experienced some difficulty in locking up on target)
Result:

46. Mission Number: 377 Aircraft Serial No. 68-0304 1.7 hours
Date: 13 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Recheck of box scan and antenna backup increment characteristics
Result:

47. Mission Number: 378 Aircraft Serial No. 68-0304 0.9 hour
Date: 14 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Repeat mission - replace previous data when
Result: radar targets were breaking up (scalloping) (spoking)

48. Mission Number: 379 Aircraft Serial No. 68-0304 1.1 hours
Date: 15 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Repeat mission to replace data when radar target
Result: was breaking up (scalloping)

49. Mission Number: 380 Aircraft Serial No. 68-0304 1.0 hour
Date: 18 August 1975
Crew: Capt. E. T. Meschko/Capt. B. G. Stohl
Radar Configuration: New feedhorn, digital auto-acq
Objective: Clutter runs
Result: 2 over land - 2 over water - data points

Total Flight Time: 70.3 hours

3.16 ANALYSIS OF FLIGHT TEST RESULTS

In tables 3-1 and 3-2 a comparison of average maximum range is shown. These data were collected in A/C 368 and 304. A minor impact of the two A/C is that each had a different indication system. A/C 368 had the Westinghouse production indicator systems and A/C 304 had the digital TI indicators. In comparing the data from A/C 368, it can be seen that there is essentially no difference in maximum range. However, A/C 304 shows an improvement in maximum range with the new feedhorn and digital auto-acq. When this method of comparison (breaklock) was chosen it was concluded by the test personnel that this was the most efficient way to accumulate the data in an unbiased manner. However, in this case when digital auto-acq was included with the new feedhorn, an additional benefit was derived (increased breaklock range) due to the bipolar boxcar which is included in the digital auto-acq circuitry. This benefit is also apparent in tracking

SEE MAJOR V. TROUY AT WRIGHT-PATTERSON AIR FORCE BASE FOR TABLE 3-1 WHICH IS A CLASSIFIED DOCUMENT UNDER SEPARATE COVER.

SEE MAJOR V. TROUY AT WRIGHT-PATTERSON AIR FORCE BASE FOR TABLE 3-2 WHICH IS A CLASSIFIED DOCUMENT UNDER SEPARATE COVER.

through the altitude line test. There is also an apparent increased breaklock range between A/C 368 and A/C 304, but as previously mentioned the two A/C had different indicators. The Westinghouse indicators (A/C 368) allowed lock-on attempts to be made at longer ranges and hence the greater breaklock range.

In figure 3-15, a summary of the altitude line tracking and auto-acq test results is given. In general these results are self-explanatory. Specifically it can be seen that when the feedhorn and then digital auto-acq are added, improvement is gained both in tracking through the altitude line and automatic acquisition. This improvement is shown most significantly over water which represents the most severe and controlled clutter environment.

To accomplish the automatic acquisition tests, it was necessary to adjust the Std. APQ-120 STC curve by approximately 6 dB. Prior to this adjustment it became obvious that the T-38 target was too small a target for consistent lock-on with a standard APQ-120 STC curve, and the objectives of this phase of the flight test program could not be accomplished without this change. The change did not affect the data collection since both the modified and standard feedhorns were using the same STC curve. It should be further noted that this change allowed locking on the T-38 at ranges in excess of visual range. Per pilot comments the visual range for a T-38 is about 3 to 3.5 miles and the STC curve, as modified, allowed lock-ons at 5 miles in the analog case and 9 miles in the digital case.

Configuration Flown	Over Land: Tracking Through Altitude Line	Over Land: Automatic Acquisition	Over Water: Tracking Through Altitude Line	Over Water: Automatic Acquisition
Std. Feedhorn Analog auto-acq.	43 attempts 37 O.K. 86% success	100 attempts 50 O.K. 50% success	39 attempts 5 O.K. 12.8% success	100 attempts 0 O.K. 0 % success
Improved Feedhorn Analog auto-acq.	41 attempts 40 O.K. 97.5% success	100 attempts 100 O.K. 100% success	40 attempts 23 O.K. 57.5 % success	100 attempts 36 O.K. 36% success
Improved Feedhorn Digital auto-acq.	41 attempts 39 O.K. 95% success	280 attempts 280 O.K. 100% success	37 attempts 27 O.K. 73% success	247 attempts 236 O.K. 95.5% success
Std. Feedhorn Digital auto-acq.	35 attempts 32 O.K. 91% success	246 attempts 238 O.K. 96.7% success	41 attempts 7 O.K. 17% success	244 attempts 133 O.K. 54% success

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Figure 3-15. Summary of Altitude Line Tracking and Auto-Acquistion Tests

3.17 CONCLUSIONS

At the conclusion of the flight test at Edwards AFB, it was apparent that the improved feedhorn and digital automatic acqusition circuits provided a significant improvement to both the performance and tactical utility of the APQ-120 Fire Control System. For many years, it had been cited by USAF flight crews that the "altitude line problem" was a deficiency in the radar. The hardware changes that were made and verified through the flights will correct that deficiency and, at the same time, provide the pilot's and WSO's with an improved capability for air combat.

The altitude line tracking was improved to such a degree that 95-100 percent successful missions were run against the T-38 target over land. Over water, the percentage was 73 percent which indicated over a 5:1 improvement.

The automatic acquisition capability was improved to a degree that 95-100 percent successful missions were conducted over land and water. The significance of this improvement can be measured by the fact that the original configuration success rate was zero over water.

The benefit of acqusitions within 1/2 second at ranges of 9 nautical miles enhances the system usefulness in air combat engagements and is far superior to present systems. The growth of this mode to elevation scan can provide additional maneuvering options to the pilot while performance radar lock for a missile launch.

The flight test was accomplished by the devoted effort of many personnel. Their time spent and expertise was invaluable in accomplishing the final results of the program.

APPENDIX A9

F-4E AUSTERE HUD/GUNSIGHT PHASE D - AVIONICS UPDATE (AN/APQ-120 ALTITUDE LINE/AUTO-ACQ) TEST PLAN

F-4E AUSTERE HUD/GUNSIGHT
PHASE D - AVIONICS UPDATE
(AN/APQ-120 ALTITUDE LINE/AUTO-ACQ)
TEST PLAN

APRIL 1975

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Commander

Operation Security

Operation Security (OPSEC) has been considered in accordance with AFR 55-30 AFSC Sup 1/AFFTC Sup 1. These provisions do not apply.

Communications Security (COMSEC) has been considered in accordance with AFR 205-7/AFSC Sup 1/AFFTC Sup 1. These provisions do not apply.

I. INTRODUCTION

A flight test program will be conducted at the Air Force Flight Test Center, Edwards Air Force Base, California, to quantitatively evaluate modifications to the AN/APQ-120 Radar. These modifications are to improve the radar automatic acquisition (Auto/Acq) capability and to improve its lock-on characteristics when the target is operating in and through the altitude line return. This test was requested by the Air Force Avionics Laboratory (AFAL) and will constitute Phase D, Avionics Update, of the Austere HUD/Gunsight Program.

The test aircraft will be F-4E S/N 68-304. The target aircraft will be a T-38. Approximately 43 sorties will be required from May through August, 1975. The flight test will be very similar to the 10db feedhorn evaluation described in AFFTC-TR-72-26.

The first series of missions will be flown to obtain baseline data on the standard production AN/APQ-120. Data will be taken to determine the maximum detection and lock-on range, the radar ability to track a target aircraft through the altitude line return, the clutter rejection and to evaluate the Auto-Acq capabilities. A modified feedhorn will replace the standard configuration and a second series of missions will be flown to repeat the tests. The third configuration will consist of modifications to LRU-17, the radar synchronizer (to enhance the altitude line rejection), and to LRU-20, to add a digital Auto-Acq capability. A third series of missions will be flown to again repeat the tests. Approximately four missions will be flown to further evaluate the Auto-Acq when used in an antenna vertical scan mode.

At the conclusion of the data flights, approximately 10 flights will be flown against a T-38 from the Aggressor Squadron at Nellis AFB. The purpose of these missions will be to evaluate the effectiveness of the Auto-Acq in ACM work.

F-4E S/N 68-304 is scheduled to go to Hill AFB, Utah, for slat modification on 3 September 1975. Priorities of tests will be established so that the schedule may be met.

II. AUTHORITY

The modifications to the AN/APQ-120 Radar were procured under contract number F33615-74-C-1173 amendment 2, and outlined in PI No. P-74-01-01 amendment 2 dated 24 March 1975. These modifications are a part of the F-4E Austere HUD/Gunsight program and evaluation will be carried out under JON 69DFCO.

III. GENERAL

A. These flight tests will be with three AN/APQ-120 radar configurations. The same data will be obtained for each.

1. Baseline Configuration

a. Antenna, P/N 663R548G01: Latest, updated antenna with AN/APX-81 dipoles and the conventional RF Suppressor Plate installed.

b. Radome, P/N 53-870052-5: Latest production radome with the AN/APX-76 tuning wire loops and lightning protection.

2. Feedhorn only configuration

a. 1db Feedhorn Balance Assembly, P/N SKFC32475-1 with RF Suppressor Plate P/N 519R153H01: RF feedhorn to improve the altitude line rejection through reduced far side lobes.

3. Modified Synchronizer and Digital Auto-Acq Configuration.

a. LRU-17: Synchronizer modification for altitude line rejection.

b. LRU-20: Digital auto acquisition modification plus solid state power supply.

c. Antenna control: Modification to permit vertical antenna scan through boresight to increase lock-on capability.

d. Error signal to computer: Installation of a buffer amplifier.

e. Beacon: C-band air-to-air ranging device.

B. The Texas Instruments Digital Scan Converter (DSC) will be used on the test aircraft so that the Austere HUD will be operational. On a non-interference basis during these tests, various symbology modifications will be qualitatively evaluated to prepare for the later phases of the Austere HUD/Gunsight program.

IV. TEST OBJECTIVES

A. To make a quantitative determination of the effects of each radar configuration on the maximum range performance of the APQ-120 radar.

B. To make a quantitative determination of the effects of each radar configuration on the amount of altitude line clutter.

C. To make a quantitative determination of the effects of each radar configuration on the ability of the radar to track a target through the altitude line return.

D. To evaluate the capabilities of the Auto-Acq mode for each radar configuration.

E. To evaluate the capabilities of the Auto-Acq mode when used in conjunction with the antenna vertical scan mode.

F. To evaluate the effectiveness of the Auto-Acq mode in an ACM environment.

V. Tasks for Participating Agencies

A. DO

1. DOT will provide the Project Manager and the Project Pilot. The Project Pilot and Project Engineer will jointly write a final report.

2. DOEE will provide a Systems Project Engineer who will provide engineering support; provide the necessary technical coordination between TAC/AFAL/and the Contractors: and jointly write the final report.

3. DOEST will prepare an Engineering Services Plan in cooperation with the Project Manager and Project Engineer. The Engineering Service Plan will include provisions for radar tracking data and space positioning, data stripouts and tabulated data, computer services, gun camera film processing and documentary photography.

B. LG

1. LGM will provide maintenance for the test and target aircraft and for the TAC T-38 during the final phase.

C. AFAL

1. AFAL will provide for the modification of the radar components, for contractor maintenance and installation of the modified hardware and will initiate the request for TAC support during the final phase.

D. TAC

1. TAC will provide the T-38 target aircraft and aircrews from the Aggressor Squadron during the final phase of the flight tests.

E. McDonnell Douglas Aircraft Company personnel assigned to the F-4E Team will maintain the test aircraft instrumentation and provide initial data reduction using AFFTC resources.

VI. Test Report

A Technical Report will be published at the conclusion of this test program.

VII. Test Procedures

A. General

1. A thorough preflight briefing will be held before each mission. Attendees will include pilots, engineers, and support personnel. Briefings will include test points to be flown, details of the tests to be performed and breakaway procedures. All aircrews will be familiar with AFFTC flying regulations, operation procedures, and any test aircraft restrictions. F-4 aircrew operating restrictions outlined in TAC M55-4 will not be exceeded.

B. Flight Tests

1. Max Range

a. Objective: To determine the effects of each radar configuration on the maximum range performance of the AN/APQ-120 radar.

b. Conditions: 30,000 feet; target airspeed 350 KIAS; test aircraft 350 KIAS ± 100 KTS.

c. Procedures: The test and target aircraft will fly co-altitude in-trail at 350 KIAS. After radar lock-on, the test aircraft will decrease speed for an opening rate of approximately 100 KTS until the radar breaks lock and the target can no longer be detected. The test aircraft will then adjust speed for a closing rate of approximately 100 KTS until radar re-detection occurs and lock-on is accomplished.

d. Support Requirements: Ground radar tracking and space positioning of the test and target aircraft may be required, and if used, a UHF tone will be transmitted to mark the plots for range determination.

e. Data Requirements: The range between the test and target aircraft will be measured on either the ground plots or the aircraft instrumentation.

2. Clutter Reduction

a. Objective: To determine the effect of each radar configuration on the amount of altitude line clutter.

b. Conditions: 20,000 and 30,000 feet; cruise airspeed: over land and over water.

c. Procedures: For the over land clutter runs, the test aircraft will be flown inbound on the 068 degree radial of the Edwards TACAN, starting 40NM out. The radar will be locked on the dry lakebed in boresight and manual track and the Vc will be set at the closing velocity. The aircraft will then fly directly over the lock-on point. A similar procedure will be used for the over water runs.

d. Support Requirements: Overwater: clearance and ground control radar monitoring while in the restricted area.

e. Data Requirements: Aircraft instrumentation recording of flight conditions, radar range and AGC.

3. Altitude Line (Land/Water):

a. Objective: To determine the effects of each radar configuration on the ability of the radar to track a target aircraft through the altitude line return.

b. Conditions: 10,000, 15,000, 20,000, 25,000, and 30,000 feet pressure altitude; cruise airspeed; over land and water.

c. Procedures: The test and target aircraft will fly in-trail at co-altitude. The radar will be locked-on the target aircraft and the range will be varied so that the target radar return passes through the altitude line return at both opening and closing rates.

d. Support Requirements: None.

e. Data Requirements: The number of times the radar breaks lock will be recorded.

4. Automatic Acquisition

a. Objective: To evaluate the capabilities of the Auto-Acq-mode for each radar configuration.

b. Conditions: 5,000, 10,000, 15,000, 20,000, and 25,000 feet pressure altitude (if a discontinuity is detected at a particular altitude, data will be taken in 1000 foot increments around that altitude); cruise airspeed; over land and water.

c. Procedures: The test and target aircraft will fly in-trail, co-altitude and co-speed. The target aircraft will be positioned so that its radar return is just beyond the altitude line return and an Auto-Acq will be attempted. Approximately 20 attempts will be made at each altitude.

d. Support Requirements: None.

e. Data Requirements: The number of successful radar lock-ons will be recorded.

5. Automatic Acquisition with Antenna Vertical Scan

a. Objective: To evaluate the effectiveness of the Auto-Acq mode when used with the antenna vertical scan mode.

b. Conditions: Test aircraft, 6,000 and 30,000 feet pressure altitude, cruise airspeed; target aircraft, varying between 6,000 feet and 30,000 feet pressure altitude, cruise airspeed +100 KTS; over land.

c. Procedures: The test aircraft will maintain cruise airspeed at 30,000 feet altitude. The target aircraft will fly co-speed and co-altitude at approximately 5NM range. The target aircraft will then reduce speed and descend until the lower gimbal limit of the radar is reached. The test aircraft will initiate auto-acq lock-ons until gimbals limits are reached. The test and target aircraft will then set up at 6,000 feet. The target will reduce speed and climb and the test will be repeated until the upper radar gimbal limit is

reached. The tests will then be repeated at high and low altitude with the target aircraft performing a series of S-turns to either side of the radar boresight line during the climb and descent. Head-on passes will be accomplished to determine the maximum lock-on range using the Auto-Agq. 1,000 feet vertical separation will be maintained.

d. Support Requirements: None.

e. Data Requirements: The number of successful radar lock-ons, the radar antenna position at lock-on, the target range, and the TISEO gimbal angle (if the target is within the TISEO gimbal limits) will be recorded on aircraft instrumentation.

6. Aggressor Squadron

a. Objective: To evaluate the effectiveness of the Auto-Acq in ACM work.

b. Conditions: Standard conditions to be determined by the Aggressor Squadron.

c. Procedures: Standard procedures and tactics to be determined by the Aggressor Squadron.

d. Support Requirements: None.

e. Data Requirements: Same as Test No. 5 above.

C. Flight Test Summary

Table I presents a summary of flights, test and radar configurations for this Test Plan.

TABLE 1

CONFIGURATION TESTS	OLD FEEDHORN	NEW FEEDHORN	MODIFIED SYNCHRONIZER NEW FEEDHORN
Max Range	4	4	4
Altitude Line/Water	2	2	2
Altitude Line/Land	2	2	2
Auto/Acq Water	2	2	2
Auto/Acq Land	2	2	2
Clutter	1	1	1
Auto Acq Fan Scan			4
Aggressor Squadron			10
TOTALS	13	13	27

APPENDIX A10

UTILITY ROUTINES

APPENDIX A10

UTILITY ROUTINES

B. 1 INTERNAL MEMORY DUMP

IC = 10001

AC = Start Address

MQ = Stop Address

B. 2 RAM DUMP

IC = 10003

AC = Start Address

MQ = Stop Address

B. 3 PAPER PUNCH ROUTINE

IC = 10005

AC = Start Address

MQ = Stop Address

Sense Switches

1. Up, Punch Protect Bit
2. Up, automatic unprotect saves
3. Not used.

B. 4 PATCH SEARCH

IC = 10007

AC = Start Address

MQ = Stop Address

Note: Make sure start tape with first chan on white line.

Printout:

Address	Old	New
↓	↓	↓
xxxxxx	xxxxxx	xxxxxx

B. 5 RAYMOND TAPE DUMP

IC = 10011

Refer to additional sheets for detailed operation.

B. 5. 1 Raymond Tape "Quick Dump" Operation

1. Put MODE number into R8MODC.

2. Choose 8 items to be dumped; get numbers from Data table.

3. To dump data in decimal format, attach prefix to data number, i. e., TAS data number = 1, prefix = 07, thus 070001 in table will printout TAS in ft/sec formatted: xxxxxx. To printout in octal prefix is 00.

4. Put data numbers with prefixs into R8TAB0, R8TAB1, and R8TAB7.

5. Sense Switch 3 up to rewind tape before dump.

6. Sense Switch 2 up to printout time, Flt. no. and mode no. for this second of data.

7. Sense Switch 1 up to printout only the first of the 16 snapshots in one second of data.

8. Start program at location 10011.

9. To examine what was recorded without dumping any data, put 7 into K8MODC and put Sense Switch 2 up; this will printout the time, flt. no., mode for each second of data.

10. The left most column indicates decimal integer number of seconds since start-up.

	ALCOSS	Tracer	Missile	A-G	SF	Decim Prefix	Units	Description	Origin
MODE	0	0	0	0	-17	00	Integer	Mode No. 0=ALCOSS, 1=TRCR, 2=MIS, 3=AGMN, 4=AGAMO	HUD
TAS	1	1	1	1	-14	07	Ft/Sec	True Airspeed	CADC
CLOCKM	2	2	2	2		00	⟶	Note: This is Double	INTR
CLOCK	3	3	3	3		00	⟶	LSB = 1/2048 Sec	INTK
ALPHA	4	4	4	4	0	25	Rad/π	Angle of Attack	CADC
RDRNG	5	5	5	5	-20	01	Feet	Radar Range	RAD
MANRGN	6	6	6	6	-20	01	Feet	Manual/Stadiometric Rgn	RDC15
RANGE	7	7	7	7	-20	01	Feet	Range Used	RDRNG MANRGN
RNGLCK	10	10	10	10	DIS	00	DIS	Range Lock	SPSEL
LOCK	11	11	11	11	DIS	00	DIS	-1=FIXED, 0=STAD, 1=RADAR	SPSEL
LNPS	12	12	12	12	-3	22	In.	Natural Log of Pressure	RDC18
HSL	13	13	13	13	-20	01	Feet	Altitude Above Sea Level	LNPS
GEES	14	14	14	14	-3	22	Mach	Mach Number	LNPS
GRHO	15	15	15	15	+8	35	Slug/ft^3	Air Density	LNPS
DSPTYP	16	16	16	16	DIS	00	DIS	Display Optional=1 Normal=0	NP
ALPHAT	17	17	17	17	-12	11	Milli-radians	Velocity Vector El	VVA
BETA	20	20	20	20	-12	11	Milli-radians	Velocity Vector Az	VVA
SPSEL	21	21	21	21	DIS	00	DIS	Discretes Input Word	RADER SWTCH
ACCMI	22	22	22	22	-3	22	g's	Lateral Acceleration	RDC09
RAC01X	23	23	23	23	–	00	RAW	Antenna Gimbal	ANRS
RAC01Y	24	24	24	24	–	00	RAW	Antenna Gimbal	ANRS
RAC02X	25	25	25	25	–	00	RAW	Antenna Gimbal	ANRS
RAC02Y	26	26	26	26	–	00	RAW	Antenna Gimbal	ANRS
RAC03X	27	27	27	27	–	00	RAW	Pitch X	INS
RAC03Y	30	30	30	30	–	00	RAW	Pitch Y	INS
RAC04X	31	31	31	31	–	00	RAW	Heading X	INS
RAC04Y	32	32	32	32	–	00	RAW	Heading Y	INS
RAC05X	33	33	33	33	–	00	RAW	Roll X	INS
RAC05Y	34	34	34	34	–	00	RAW	Roll Y	INS
RAC06X	35	35	35	35	–	00	RAW	Pitch Rate	FCGA
RAC06Y	36	36	36	36	–	00	RAW	Roll Rate	FCGA
RAC07X	37	37	37	37	–	00	RAW	Lateral Acc	FCGA
RAC07Y	40	40	40	40	–	00	RAW	Yaw Rate	FCGA

HUD – HUD Switches
CADC – Air Data Computer
INTR – AYK8 Internal
RAD – Radar
STRP – Stad Range Pot.
SPSEL – Discrete Inputs Word
NP – NAV Panel
ID – Instrum Triad
ANRS – Antenna Resolvers
INS – Inertial Nav. System
FCGA – Flight Control Gyro Amp
VVAL – Velocity Vector Algorithms

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	ALCOSS	Tracer	Missile	A-G	SF	Decim Prefix	Units	Description	Origin
RAC08X	41	41	41	41	–	00	RAW	Angle of Attack	CADC
RAC08Y	42	42	42	42	–	00	RAW	18V Ref Voltage	CADC
RAC09X	43	43	43	43	–	00	RAW	Normal Acceleration	FCGA
RAC09Y	44	44	44	44	–	00	RAW	Dummy Half	–
RDC01	45	45	45	45	–	00	RAW	Radar Range	RAD
RDC02	46	46	46	46	–	00	RAW	Range Rate	RAD
RDC03	47	47	47	47	–	00	RAW	Antenna Az Rate	RAD
RDC04	50	50	50	50	–	00	RAW	Antenna El Rate	RAD
RDC05	51	51	51	51	–	00	RAW	Pitch Rate	I Δ
RDC06	52	52	52	52	–	00	RAW	Yaw Rate	I Δ
RDC07	53	53	53	53	–	00	RAW	Roll Rate	I Δ
RDC08	54	54	54	54	–	00	RAW	Long.Acceleration	I Δ
RDC09	55	55	55	55	–	00	RAW	Lateral Acceleration	I Δ
RDC10	56	56	56	56	–	00	RAW	Normal Acceleration	I Δ
RDC11	57	57	57	57	–	00	RAW	Velocity North	INS
RDC12	60	60	60	60	–	00	RAW	Velocity East	INS
RDC13	61	61	61	61	–	00	RAW	Velocity Vertical	INS
RDC14	62	62	62	62	–	00	RAW	True Airspeed	CADC
RDC15	63	63	63	63	–	00	RAW	Stad Range	STRP
RDC16	64	64	64	64	–	00	RAW	Natural Log of Pressure	CADC
THEDT1	65	65	X	X	0	25	Rad/Sec	Pitch Rate	RDC05
PSIDT1	66	66	X	X	0	25	Rad/Sec	Yaw Rate	RDC06
PSIDT1	67	67	X	X	-2	23	Rad/Sec	Roll Rate	RDC07
ACCL	70	70	X	X	-3	22	g's	Longitud Accel	RDC08
ACCN	71	71	X	X	-4	21	g's	Normal Accel	RDC10
RDOT	72	72	71	X	-14	07	Ft/Sec	Range Rate	RDC02
RNDS	73	73	X	X	-17	04	Number of Rnds	Rounds Remaining	INTR
WGSPN	74	74	X	X	-17	04	0–DRT, 1–FIG, 2–25', 2–37'	Wingspan Number	NP
GUNTST	75	75	X	X	-17	00	0-OP, 1-TST 1, 2-TST 2	Gunnery Test Switch	NP

CADC – Air Data Computer
FCGA – Fight. Control Gyro Amp
RAD – Radar
I Δ – Instrument Triad

INS – Inertial Nav
STRP – Stad Range Pot.
INTR – Internally Generated
NP – Nav. Panel

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	ALCOSS	Tracer	Missile	A-G	SF	Decim Prefix	Units	Description	Origin
THEDT2	76	X	X	X	0	25	Rad/Sec	Pitch Rate	RAC06
PSIDT2	77	X	X	X	0	25	Rad/Sec	Yaw Rate	RAC07
PHIDT2	100	X	X	X	-2	23	Rad/Sec	Roll Rate	RAC06
ACCM2	101	X	X	X	-3	22	g's	Lateral Acceleration	RAC07
ACCN2	102	X	X	X	-4	21	g's	Normal Acceleration	RAC09
DETNT1	103	X	X	76	DIS	00	0-Off 1-On	Trigger 1	Pilot Pickle
DETNT2	104	X	X	77	DIS	00	0-Off 1-On	Trigger 2, Bomb Pickle	Pilot Pickle
GLPSI	105	X	X	X	0	25	Radians	Alcoss Pipper X position	HON
GLTHE	106	X	X	X	0	25	Radians	Alcoss Pipper Y position	HON
GLRAD	107	X	X	X	0	25	Radians	Alcoss Pipper Radius	HON
GPSIM1	X	76	X	X	0	25	Radians	1000 Ft Range Bar Left X	HON
GPSIM2	X	77	X	X	0	25	Radians	1000 Ft Range Bar Left X	HON
GPSIM3	X	100	X	X	0	25	Radians	3000 Ft Range Bar Left X	HON
GTHEM1	X	101	X	X	0	25	Radians	1000 Ft Range Bar Y	HON
GTHEM2	X	102	X	X	0	25	Radians	2000 Ft Range Bar Y	HON
GTHEM3	X	103	X	X	0	25	Radians	3000 Ft Range Bar Y	HON
GHBXP	X	104	X	X	0	25	Radians	Radar Diamond X	HON
GHBXT	X	105	X	X	0	25	Radians	Radar Diamond Y	HON
GHCIR	X	106	X	X	0	25	Radians	Stad Circle X	HON
GHCIR+1	X	107	X	X	0	25	Radians	Stad Circle Y	HON
CLAMDA	X	X	65	X	0	25	Cosine	Cosine Antenna Az	RAC01
SLAMDA	X	X	66	X	0	25	Sine	Sine Antenna Az	RAC01
CLAMDE	X	X	67	X	0	25	Cosine	Cosine Antenna El	RAC02
SLAMDE	X	X	70	X	0	25	Sine	Sine Antenna El	RAC02
RDOT	X	X	71	X	-14	07	Ft/Sec	Range Rate - = Closing	RDC02
OMEGA1C	X	X	72	X	0	25	Rad/Sec	Antenna Az Rate	RDC03
OMEGAJ	X	X	73	X	0	25	Rad/Sec	Antenna El Rate	RDC04
ERAZ	X	X	74	X	0	25	Radians	Steering Error Azimuth	MSAL
EREL	X	X	75	X	0	25	Radians	Steering Error Elevation	MSAL
ASE	X	X	76	X	0	25	Radians	Allowable Steering Error	MSAL
BREAKX	X	X	77	X	DIS	00	0-No 1-Break	Breakaway	MSAL
BANG	X	X	100	X	DIS	00	0-No 1-Shoot	Shoot Light Discrete	MSAL
RAMIN	X	X	101	X	-20	01	Feet	Minimum Range	MSAL
RAMAX	X	X	102	X	-20	01	Feet	Maximum Range	MSAL

FCGA – Flight Control Gyro Amp
HON – Honeywell Gunnery Routines
MSAL – Missile Algorithms

75-0837-TA-16C

	ALCOSS	Tracer	Missile	A-G	SF	Decim Prefix	Units	Description	Origin
RSU	X	X	103	X	-20	01	Feet		MSAL
PIPDAZ	X	X	104	X	-12	11	Mils	Steering Bug Azimuth	MSAL
PIPDEL	X	X	105	X	-12	11	Mils	Steering Bug Elevation	MSAL
TGTCPX	X	X	106	X	-12	11	Mils	Target Designator Azimuth	MSAL
TGTCPY	X	X	107	X	-12	11	Mils	Target Designator Elevation	MSAL
CTHETA	X	X	X	65	0	25	Cosine	Cosine of Pitch Angle	RAC03
STHETA	X	X	X	66	0	25	Sine	Sine of Pitch Angle	RAC03
CPSI	X	X	X	67	0	25	Cosine	Cosine of Heading	RAC04
SPSI	X	X	X	70	0	25	Sine	Sine of Heading	RAC04
CPHI	X	X	X	71	0	25	Cosine	Cosine of Roll Angle	RAC05
SPHI	X	X	X	72	0	25	Sine	Sine of Roll Angle	RAC05
VELN	X	X	X	73	-14	07	Ft/Sec	Velocity North	RDC11
VELE	X	X	X	74	-14	07	Ft/Sec	Velocity East	RDC12
VELV	X	X	X	75	-14	07	Ft/Sec	Vertical Velocity	RDC13
DETNT1	103	X	X	76	DIS	00	0-On 1-Off	Trigger 1	Pilot Pickle
DETNT2	104	X	X	77	DIS	00	0-On 1-Off	Trigger 2, Bomb Pickle	Pilot Pickle
PIPPAZ	X	X	X	100	-12	11	Mils	Impact Pipper Azimuth	AGAL
PIPPEL	X	X	X	101	-12	11	Mils	Impact Pipper Elevation	AGAL
AGSOLN	X	X	X	102	-17	04	Presets Number	A-G Solution Number	NP
AGMPLY	X	X	X	103	-12	11	Mils	A-G Manual Dive Angle	AGMR
AGMPY	X	X	X	104	–	00	–	–	
AGMRY	X	X	X	105	-12	11	Mils	A-G Manual Pipper Y	AGMA
AGTGHT	X	X	X	106	-17	04	Feet	Target Height	NP
AGTYP	X	X	X	107	DIS	00	–	A-G Type Discrete	

MSAL – **Missile Algorithms**
AGAL – **A-G Automatic Algorithms**
AGMR – **A-G Manual Routine**
NP – **NAV Panel**

75-0837-TA-16D

DECIMAL DATA FORMAT (PLACEMENT OF DECIMAL POINT)

Prefix	Scale Factor		Format	Mult.
00	Discrete		Octal	
01	−20		XXXXXXO	104,858
02	−19		XXXXXXO	52,429
03	−18		XXXXXXO	26,215
04	−17		XXXXXX	131,071
05	−16		XXXXXX	65,536
06	−15		XXXXXX	32,768
07	−14		XXXXXX	16,384
10	−13		XXXXXX	81,920
11	−12		XXXXXX	40,960
12	−11		XXXXXX	20,480
13	−10		XXXXXX	102,400
14	−9		XXXXXX	51,200
15	−8		XXXXXX	25,600
16	−7		XXXXXX	128,000
17	−6		XXXXXX	64,000
20	−5		XXXXXX	32,000
21	−4		XXXXXX	16,000
22	−3		XXXXXX	80,000
23	−2		XXXXXX	40,000
24	−1		XXXXXX	20,000
25	0		XXXXXX	100,000
26	+1		XXXXXX	50,000
27	+2		XXXXXX	25,000
30	+3		XXXXXX	125,000
31	+4		XXXXXX	62,500
32	+5		XXXXXX	31,250
33	+6		XXXXXX	15,625
34	+7		OXXXXXX	78,125
35	+8		OXXXXXX	39,063
36	π	Radians	XXXXXX	31,415

75-0837-T-17

DESIRABLE DATA FOR EACH MODE

ALCOSS Mode Number 0

	Pass No. 1		Pass No. 2	
27027	Mode No.	000000	Mode No.	000000
27030	PHIDTI	230067	ACCL	220070
27031	THEDTI	250065	ACCMI	220022
27032	PSIDTI	250066	ACCN	210071
27033	ALPHA	250004	RANGE	010007
27034	GRHO	350015	GLPSI	250105
27035	GEES	270014	GLTHE	250106
27036	TAS	070001	GLRAD	250107
27037	RDOT	070072	BETA	110020

TRACER Mode Number 1

	Pass No. 1		Pass No. 2	
27027	Mode No.	000001	Mode No.	00001
27030	PHIDTI	230067	ACCL	220070
27031	THEDTI	250065	ACCMI	220022
27032	PSIDTI	250066	ACCN	210071
27033	ALPHA	250004	RANGE	010007
27034	GRHO	350015	GHBXP	250104
27035	GEES	220014	GHPXT	250105
27036	TAS	070001	GHCIR	250106
27037	RDOT	070072	GHCIR+1	250107

MISSILE

	Pass No. 1		Pass No. 2	
27027	Mode No.	000002	Mode No.	000002
27030	RANGE	010007	CLAMEA	250065
27031	RNGLGK	000010	SLAMDA	250066
27032	HSL	010013	CLAMDE	250067
27033	GRHO	350015	SLAMDE	250070
27034	ALPHAT	110017	RDOT	070071
27035	BETA	110020	ERAZ	250074
27036	OMEGAJ	250072	EREL	250075
27037	OMEGAK	250073	SHDISC	000100

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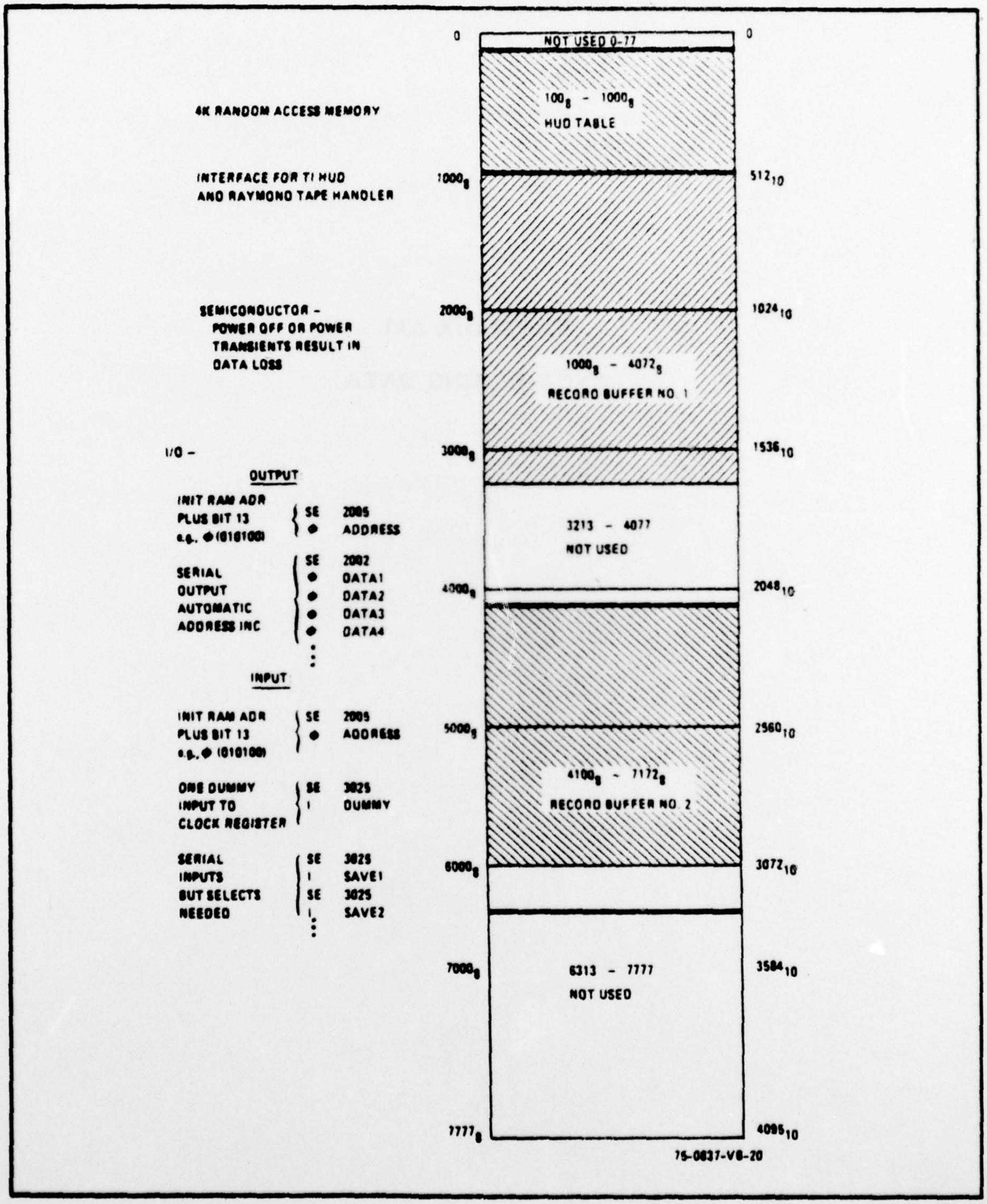
A–G MANUAL Mode Number 3

27027	Mode No.	000003
27030	TAS	070001
27031	HSL	010013
27032	STHETA	250066
27033	AGSOLN	040102
27034	AGMPLY	110103
27035	PIPPEL	110101
27036	AGTGHT	04016
27037	VELV	070075

A–G AUTO Mode Number 4

	Pass No. 1		Pass No. 2	
27027	Mode No.	000004	Mode No.	000004
27030	TAS	070001	CPHI	250071
27031	HSL	010013	SPHI	250072
27032	ALPHAT	110017	VELN	070073
27033	BETA	110020	VELE	070074
27034	CPHETA	250065	VELV	070075
27035	STHETA	250066	PIPPAZ	110101
27036	CPSI	250067	PIPPEL	110102
27037	SPSI	250070	AGTIGHT	040106

75-0837-T-19



Austere Hud Ram Map

APPENDIX A11

ENGINEERING DATA

COMPUTER HARNESS MODIFICATION

Signal	Computer	Wire Size	Wire Number	Destination	Mnemonic	Note
Antenna Az Cmd	28P6/64	TPS 22 (1)	FT-AA-100	19J4/P	CAZ	New TPS
Antenna Az Cmd RTN	28P6/65	TPS 22 (1)	FT-AA-101	19J4/Q	CAZR	
Antenna EL Cmd	28P6/66	TPS 22 (2)	FT-AA-102	19J4/M	CELC	New TPS
Antenna EL Cmd RTN	28P6/67	TPS 22 (2)	FT-AA-103	19J4/N	CELCR	
EL ERR SIG	28P6/68	TPS 22 (3)	FT-HUD-134B22	19J1/K		New TPS
EL ERR SIG RTN	28P6/69	TPS 22 (3)	FT-HUD 135B22	19J1/D		
AZ ERR Sig	28P6/91	TPS 22 (4)	FT-HUD 140B24	19J1/Y		Remove from 28P6/28 and insert in 28P6/91 Name change
AZ ERR SIG RTN	28P6/27	TPS22 (4)	FT-HUD 139B24	19J1/C		Name change
28V STOP SCAN	28P5/15	#22	FT-HUD 183B22	19J2/T		Add wire
28V AUTO ACQ	28P5/16	#22	FT-HUD 180B22	19J2/X		Add wire
Computer Dominant	29P1/3*	1/2 TPS BRN	FT-HUD 137B22	19J1/J		Remove pin from 29P1/13 and insert in 29P1/3
			FT-HUD 137C22	19J4/R		And segment

*Remove existing wire from 29P1/3 and tie back

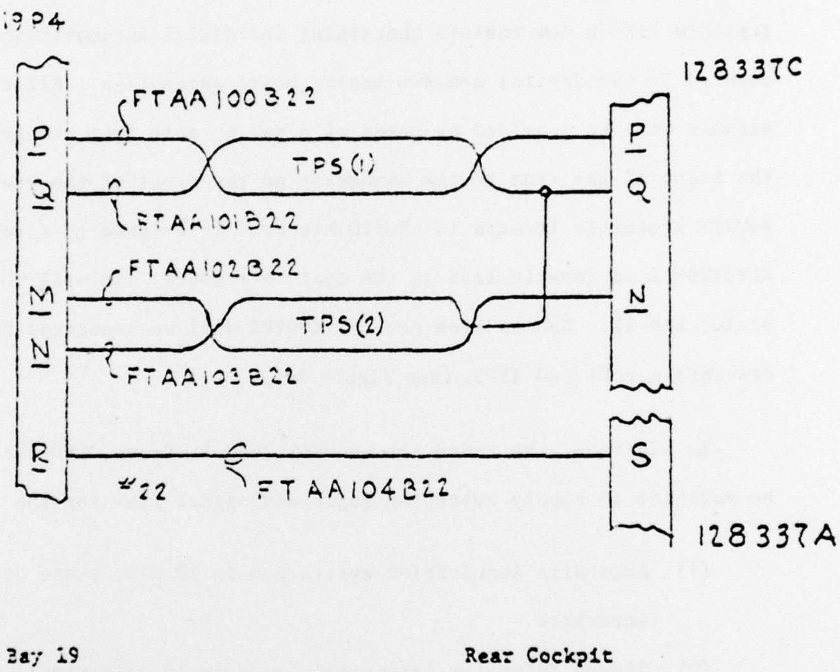
AUTOMATIC ACQUISITION

WIRE MODIFICATION AT LRU-1 CONNECTORS

1. Remove pin from 1P1/FF and insert in 1P1/X.
2. Remove pin from 1P1/BB and jumper the wire to 1P2/W.
3. Remove pin from 1P3/L and jumper the wire to 1P2/M.
4. Remove pin from 1P3/P and jumper the wire to 1P2/E.
5. Remove pin from 1P3/P and jumper the wire to 1P2/F.
6. Remove pins from 1P3/N and 1P3/Q, splice together and jumper the wires to 1P2/

AIRCRAFT WIRING CHANGES FOR AUTOMATIC ACQUISITION SCAN

Select two sets of TPS and one #22 wire from the 117 wire bundle (cable group 3). Terminate these wires in Bay 19 and at the TISEO LOGIC BOX jumper connectors as shown



LRU/SYSTEM CHANGES FOR DIGITAL AUTOMATIC ACQUISITION

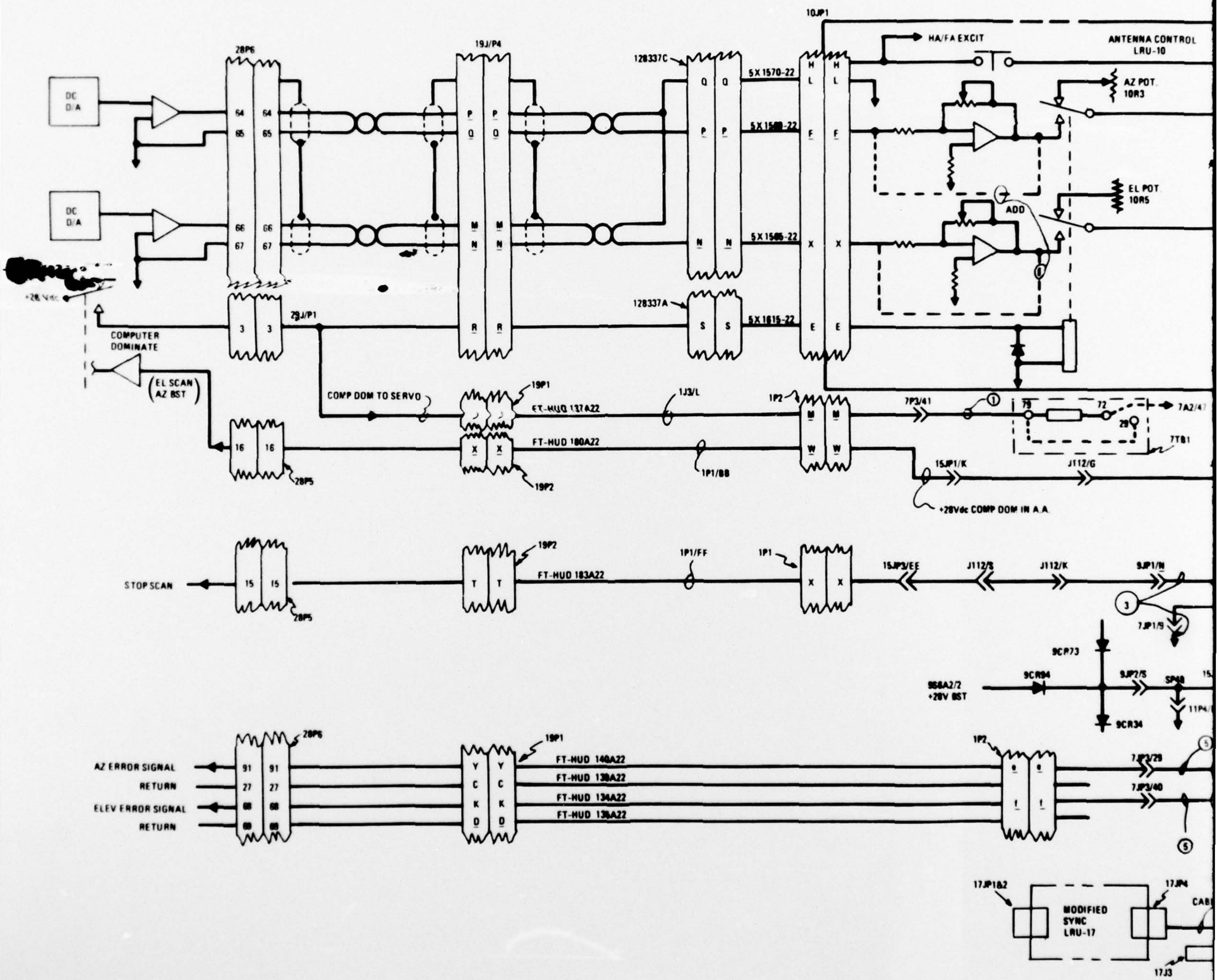
To incorporate digital automatic acquisition capability into the APQ-120 system for evaluation with minimum changes to the aircraft and system wiring, the following changes will be made. The pump tube power supply, LRU-20 will be replaced with a new chassis containing the ditial automatic acquisition circuitry mounted on two digital and two analog board assemblies. All the input power and signals will be provided by means of a patch cable from the test connector on the front of the sync to the connector on the front of the new LRU-20. The (-) 600VPS presently located in LRU-20 has been redesigned to accommodate only the KLYSTRON load (static load in LNA must be removed) and will be mounted in pulse stalo, LRU-21. Cables from new (-) 600VPS will be connected between existing connectors 20P1 and 19P5. (see figure C-1).

In addition, the radar set control, LRU-9, Servo, LRU-7 and Sync, LRU-17, will be modified to supply switching logic and signal flow for the following:

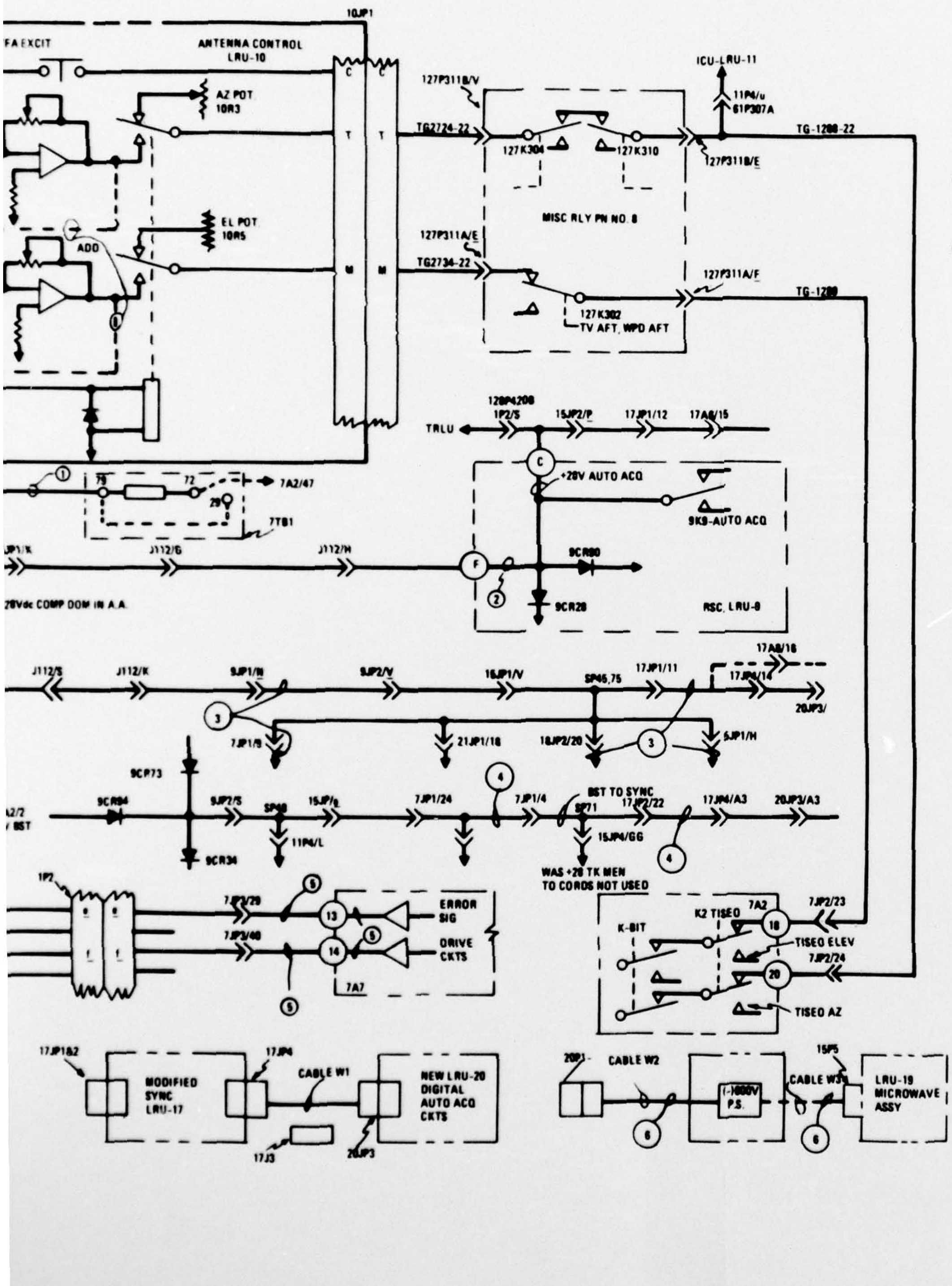
(1) Automatic Acquisition excitation in 10 mile range without BST interlock.

(2) Slaved automatic Acquisition mode in 10 mile range - this mode will have an approximate 8 mile automatic acquisition range sweep with computer command of antenna (elev scan and Az BST).

(3) Normal automatic acquisition in BST in 5 mile or 10 mile range (NOTE: in the 5 mile range the auto acq range sweep will be approximately 8 miles long and if during evaluation this presents a problem the 5 mile auto acq range selection will be deactivated by disconnecting wire on 9S7A1/4).



DC D/A
DC D/A
28P6
19J/P4
128337C
10JP1
HA/FA EXCIT
ANTENNA CONTROL LRU-10
5X1570-22
5X1586-22
5X1616-22
AZ POT. 10R3
EL POT 10R5
ADD
+28 Vdc
128337A
29J/P1
COMPUTER DOMINATE
EL SCAN
AZ BST
COMP DOM TO SERVO
19P1
FT-HUD 137A22
1J3/L
1P2
7P3/41
7A2/47
7TB1
FT-HUD 180A22
1P1/BB
19P2
28P5
15JP1/K
J112/G
+28Vdc COMP DOM IN A.A.
STOP SCAN
FT-HUD 183A22
1P1/FF
1P1
15JP3/EE
J112/S
J112/K
9JP1/N
7JP1/9
9CR73
9CR94
9S6A2/2 +28V BST
9JP2/S
9CR34
AZ ERROR SIGNAL
RETURN
ELEV ERROR SIGNAL
RETURN
FT-HUD 140A22
FT-HUD 139A22
FT-HUD 134A22
FT-HUD 135A22
7JP3/29
7JP3/40
17JP1&2
MODIFIED SYNC LRU-17
17JP4
17J3



(1) THRU (6) SEE SEPARATE SHEETS FOR DETAILS OF CHANGE (SK C3 51975-1

(7) BEACON LOCK-ON: TO PERMIT LOCK-ON IN BEACON MODE REMOVE 9CR13 IN RSC, LRU-9. THIS PREVENTS 9K8, ACQ PREVENT, RELAY BEING OPERATED IN BEACON MODE.

(8) 10 MILE AUTO ACQ: TO EFFECT AUTO ACQ IN 10 MILE RNG, INDEPENDENT OF BST, INSTALL JUMPER IN RADAR SET CONTROL FROM 9S7B2/8 TO 9S7A1/5. THEN GOING TO BST IN 10 MILE RNG GIVES 10 MILE-BST-AUTO ACQ. 5 MILE-BST AUTO ACQ WOULD REMAIN AS IS EXCEPT AUTO ACQ SWEEP IS APPROX 8 MILES LONG. IF THIS CAUSES PROBLEMS THEN TO ELIMINATE 5 MILE-A.A. DISCONNECT WIRE AT 9S7A1/4, INSULATE AND TIE BACK TO CABLE.

NOTES:

1. DETAILS OF LRU MODS ARE ON SEPARATE SHEETS
2. COMPUTER MODS NOT SHOWN
3. OTHER SYNC MODS FOR DIGITAL A.A. ARE NOT SHOWN ON THIS DWG.

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Figure C-1. APQ-120 Digital Auto Acquisition Mod

2

(4) To eliminate the necessity of changing the LRU-15 cable assembly wiring, unused cords wires and aspect switch signals leads in servo, R.S.C. and sync will be relocated to provide signal flow for digital auto acq signals.

Also to be provided are Az and Elev error signal outputs to be used by auxiliary system. The 7A7 PWA in servo will be modified to install output driver circuits. Wires normally used for $\pm5°E_s$ Step signals will be used in servo to provide these outputs.

One wire in each the pulse trans, LRU-5 and Rt Elec., LRU-18 will be disconnected to prevent cords mode of operation in these LRU's.

Detailed LRU Modifications - Refer to drawing SKCB51975

2 computer dominate in Auto Acq to computer: A +28 VDC signal will be provided in 10 mile range when auto acq is initiated to provide elev scan and az BST in auto acq. This signal will be provided from R.S.C. on the lead normally providing aspect volts to computer.

(A) On R.S.C. push out pin 9J1/F, identify, insulate and tie back to cable for later restoration.

(B) Install new pin with lead in 9J1/F and route lead to plate end of 9CF28 on relay shelf. Solder connection.

1 Computer dominate to servo: A +28 VDC signal will be supplied to servo to operate acq, stab out and single bar scan relays in servo same as when servo is in VISUO dominate mode. The lead normally supplying

900 cy 0° to computer 7J3/41 will be re-
located to provide this signal.

(A) On servo, LRU-7 push out pin 7J3/41, identify, insulate and tie back to cable. (Other end goes to XA10/8).

(B) Install new pin in 7J3/41 with lead and route to 7TB1 and connect to TB1/79.

(C) Install diode on TB1 between terminals 79 and 72 (cathode end at terminal 79).

(D) Disconnect lead on TB1/72, (other end is connected to 7A2/47) and connect to TB1/72.

(E) Add jumper between TB1/79 and TB1/29.

(F) Solder all connections.

3 Stop scan signal to computer: A +28 VDC signal will be sent from sync to computer in auto acq when target detect circuit provides signal. To get signal to computer the unused cords select wire will be used to route the signal to R.S.C. where it will be jumpered to tail aspect signal lead which goes to the computer. Some of the other terminations of these wires will be disconnected.

(A) On R.S.C. push out pin 9J1/N, identify, insulate and tie to cable.

(B) On RSC push out pin 9J2/V, identify, insulate and tie to cable.

(C) On RSC add new jumper between pins 9J1/N and 9J2/V.

(D) On pulse trans, push out pin 5P1/H, identify, insulate and tie to cable.

(E) On servo push out pin 7J1/9, identify, insulate and tie to cable.

(F) On R.T. elec push out pin 18J2/20, identify, insulate and tie to cable.

(G) On sync disconnect 17A6/23 (other end connects to 17J1/11) and reconnect to 17A6/16. (This is in addition to lead on 17A6/16.)

4 BST to Sync: To provide BST auto acq signal to sync the unused +28V track memory lead between sync and servo will be used.

(A) In sync push out pin 17J2/22, identify, insulate and tie to cable.

(B) Install new pin in 17J2/22 with lead and connect to 17J4/A3.

(C) In servo disconnect 7A18/26 (other ends connects to 17J1/4) and reconnect to 7A18/49. (This is in addition to wire presently on 7A18/49.)

6 Digital auto acq unit (new LRU-20): To provide space for new digital auto acq circuits the pump tube power supply is to be replaced with new unit. The new unit will be connected to the system by means of a patch cable connecting to the test connector on the sync. The (-) 600 V.P.S. presently in the P.T.P.S. has been redesigned, repackaged and will be mounted on the pulse stalo, LRU-21. Cables from the (-) 600 V.P.S. will connect to 20P1 and 19P5. By connecting to 19P5 the static load on the LNA will be removed.

(A) Pump tube power supply, LRU-20

(1) Remove pump tube power supply, LRU-20.

(2) Connector 20P2 should be tied down as this cable will not be used when new digital auto acq unit is installed.

(3) Disassemble connector 20P1 from its present equipment rack mounting location and push back into equipment rack. This connector 20P1 will be reconnected to new (-) 600 V.P.S.

(4) Install new LRU-20 into equipment rack.

(B) Synchronizer, LRU-17

(1) Remove sync, LRU-17.

(2) Install modified sync, LRU-17 supplied by Westinghouse.

(3) Install patch cable from sync, LRU-17 to new LRU-20 20P3.

(C) Pulse stalo, LRU-21

(1) Remove pulse stalo, LRU-21 from equipment rack.

(2) Remove hat section, 514R123G01 with 21A3, Beacon, Osc-multi.

(3) Remove 21A3 unit from hat section and install on new hat section.

(4) Install new (-) 600 V.P.S. on new hat section.

(5) Install new hat section into pulse stalo.

(6) Install pulse stalo into equipment rack.

(7) Connect input cable from (-) 600 V.P.S. to connector 20P1 (removed from mounting in step 6(A)(3).

(8) On microwave assembly, LRU-19, disconnect 19P5 and tie down.

(9) Connect output cable from (-) 600 V.P.S. to 19J5.

5 Error signal output to computer: To provide error signal outputs to computer. The 7A6 PWA in servo is be modified to provide Az and Elev error signal output drivers. For evaluation phase existing wires between servo and computer will be used to provide these functions. These changes are not part of the ditial auto acq modifications.

(A) Modification information to be supplied under separate coverage.